DISCOVERY

THE PROGRESS OF SCIENCE

SIR FREDERICK BRUNDRETT
Chapman Pincher

A BRITAIN WITHOUT RABBITS?
H. N. Southern, *M.A.*

THE ORIGIN AND EVOLUTION OF COAL
P. J. Adams
B.Sc., F.G.S.

MICHAEL FARADAY
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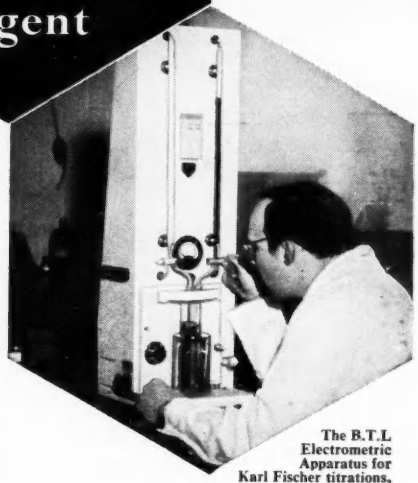

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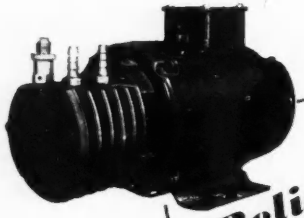

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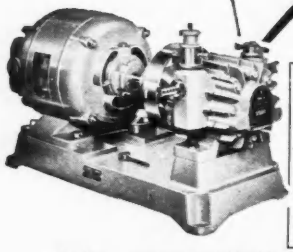

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DISCOVERY

THE MAGAZINE OF SCIENTIFIC PROGRESS

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THE PROGRESS OF SCIENCE

GENETIC HAZARDS AND THE HYDROGEN BOMB

What precisely triggered off the great outburst in March over the permanent genetic effects that might be produced by fission products generated by atomic and thermonuclear weapons, it is hard to say. Possibly the beginning of it all was the statement that the fall-out of one of these bombs could cover an area of 7000 square miles or more. This was followed by demands that test explosions ought to be given up because of the genetic hazard. In particular there was the proposal of the Federation of American Scientists for the setting up of a United Nations commission to study and assess the potential dangers in atomic and H-bomb tests. (The full text of this was printed by *The Times* on March 24.) The scientific contribution to this "chain reaction" that culminated in the debate in the House of Commons on March 22 was comparatively small, and the amount of enlightenment which the public received on scientific aspects of the matter was small indeed.

Proof that ionising radiations can induce mutations in living organisms was given about a quarter of a century ago, when Prof. Muller produced mutations in the fruit fly (*Drosophila*) *by* x-ray bombardment. Since then a great deal of similar experimental work has been done, using not only x-rays but the radiation from a variety of radioactive substances. The scientists who have worked in this field lost no time after Hiroshima to warn the world of the genetic risks introduced by the fission products from atomic bombs.

It is, of course, the high energy radiation from radioactive substances that renders the latter dangerous genetically. The major points about their genetic effects is well summed up by Prof. A. H. Sturtevant of the California Institute of Technology in a recent address to the American Association for the Advancement of Science on the subject of "The Social Implications of the Genetics of Man" (see *Science*, 1954, Vol. 120, p. 405). Prof. Sturtevant said that the main generalisations which emerge from all the work that has been done on the irradiation of experimental organisms are as follows:

(*i*) High-energy irradiation produces mutations.

(*ii*) The frequency of induced mutations is directly proportional to the dosage of irradiation. There is almost certainly no threshold value below which irradiation is ineffective.

(*iii*) The effects of successive exposures are cumulative.

(*iv*) The effects are permanent in the descendants of the affected genes. There is no recovery.

(*v*) The overwhelming majority of these mutations is deleterious—that is, they seriously affect the efficiency of individuals in later generations in which they come to expression. These deleterious genetic effects may lead to early death or to any of a wide variety of defects, often gross ones. There is a store of such undesirable genes already present in any population. What irradiation does is to add to this store.

There is one other important point to be borne in mind when one considers the results obtained with experimental animals and their relevance to man's heredity. Prof. Sturtevant stated in the address which we have cited that the quantitative results obtained from one organism cannot safely be applied to a wholly different kind of organism, but he stressed that this does not affect the validity of the generalisations listed above.

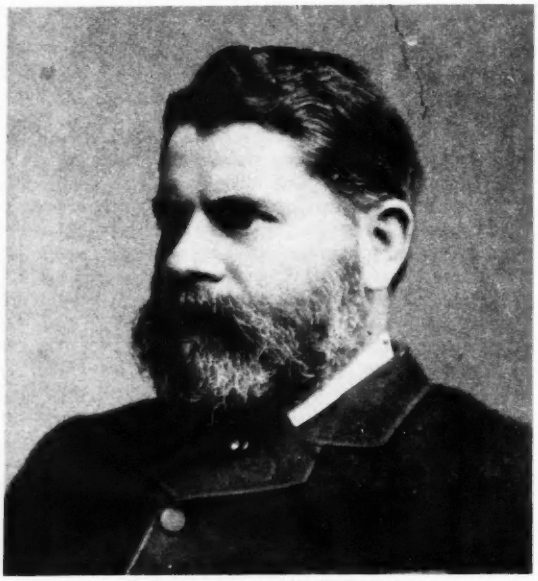
Prof. C. H. Waddington, in a letter to *The Times* supporting the proposal of the Federation of American Scientists for the creation of a special United Commission, emphasised the need to study the effect of radiation on mammals, pointing out the inadequacy of relying on results obtained with fruit flies. He believed that the only relevant British research being done on mammals was that being carried out by a small Medical Research Council Group in the Institute of Animal Genetics, Edinburgh, of which he is head.

The Minister of Health, Mr. Macleod, speaking in the Commons debate on this subject on March 22, did not query this last-mentioned point of Prof. Waddington,

though apparently similar work on the genetic effects of radiation on mice is being done at Harwell. The Minister was mainly concerned with discussing what increase in atmospheric radioactivity had resulted from successive atomic and hydrogen bomb tests. One assessment of this increase which has been widely quoted is that given in the report of the U.S. Atomic Energy Commission entitled "The Effects of High-Yield Nuclear Explosions" and issued on February 15 this year. This report stated that:

> "In general, the total amount of radiation received by residents of the United States from all nuclear detonations to date, including the Russian and British tests and all of our own tests in the United States and the Pacific, has been about one-tenth of one roentgen. This is only about one-hundredth of the average radiation exposure inevitably received from natural causes by a person during his or her reproductive lifetime. It is about the same as the exposure received from one chest x-ray."

Mr. Macleod said that there were two reasons why this estimate should be considered to err on the high side. First of all, this figure was calculated on the assumption that the hypothetical person under consideration stands outside in the open for twenty-four hours a day for about fifty years, and that of course is improbable. According to the extent that he is indoors or under cover the figure will be considerably reduced. It also assumes that none of the activity weathers away from the surface of the ground, which, of course, would happen. "Therefore, I am advised that the effective average dose that would have been received by somebody in this country from all the bombs that have been exploded so far is a very great deal less than ·03 roentgen," said Mr. Macleod. He went on to say that this level of radiation was considerably lower than the "maximum permissible level" which had been agreed internationally to be safe for radiologists and workers using radio-isotopes. This accepted level is 0·3 roentgen per week, or about 15 roentgens per year. He cited figures given him by experts as to the dose of radiation that would double the ordinary spontaneous mutation rate in organisms: he said he had found considerable disagreement here, but he said that he was told that a figure of 50 roentgens over twenty-five years is as good a guess as we can make. It does seem reasonable to conclude that in spite of all the radioactive particles thrown into the air by atomic and hydrogen bomb explosions the mutation rate of man has not been changed significantly. Nevertheless, nobody is going to take lightly the genetic risk which atomic bomb trials has introduced. Public concern on the subject will almost certainly lead to radiobiological research being carried out on a greater scale than at present. According to the Minister of Health, the Medical Research Council is spending over £200,000 a year on such work, and he made it clear that the British Government would be prepared to consider increased financial support for such research. Only a small fraction of that £200,000 is spent on genetical research, it should be noted.

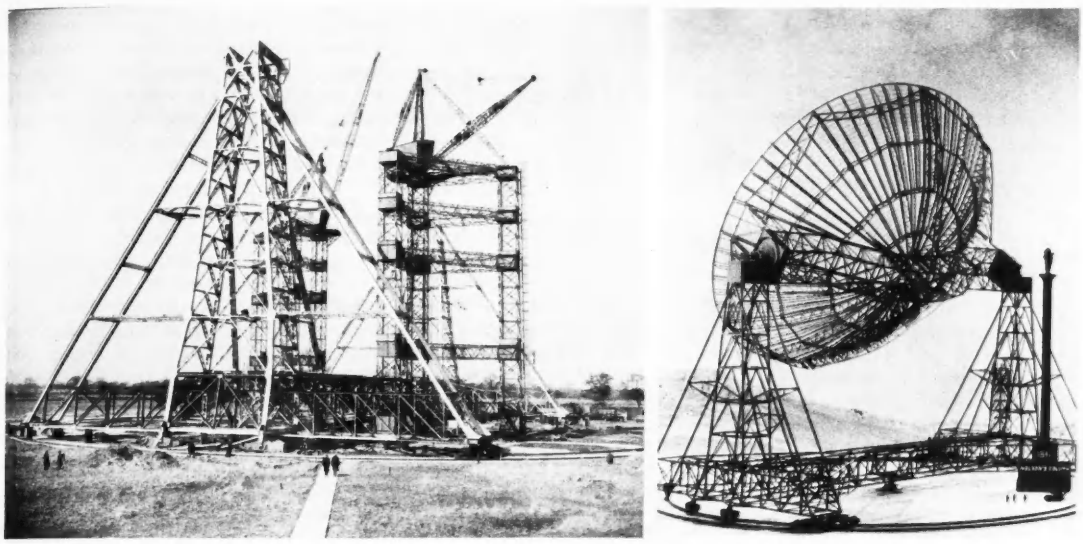


George E. Davis (1850–1907) pioneer of chemical engineering in Britain.

One of the main demands made in the Commons debate was for an international congress which could bring together all existing information on the subject of genetic risks of atomic explosions. There seemed, however, to be little awareness that radiobiologists all over the world already exchange the results of their investigations, and that they already meet at international conferences such as the Liége radiobiology symposium of 1954. A similar meeting is to be held this August in Cambridge.

Another possible line of action that has been suggested is that a U.N. commission should keep a watch on the level of atmospheric radioactivity all over the world. Continuous monitoring to collect such data goes on in Britain and the U.S.A., and presumably in the U.S.S.R. as a piece of routine military intelligence work. At present the figures collected come under the screen of military secrecy, and it does seem somewhat problematical whether any scheme for collecting such data on a world-wide basis and pooling the data internationally could be made to work. However, the possibility of organising such a scheme is under study, we understand, by the World Meteorological Organisation.

The Minister of Health was right to point out that the only final answer to the problem of radioactive contamination of the atmosphere that has been going on since 1945 is a comprehensive scheme of disarmament. There is, perhaps, some small measure of comfort in the fact that no nation is going to waste atomic explosives in needless tests. The number of atomic and hydrogen bomb tests is kept low because of the need for economy of explosive material. The consideration of the genetic hazards can be valuable at the present time if for no other reason that it can increase the general realisation that in a world war with atomic weapons all nations will be on the losing side.



THE RADIO TELESCOPE AT JODRELL BANK. (*Left*) This photograph shows how far the construction of the telescope had progressed by the end of March. The amount of structural work that remains to be done can be appreciated from a comparison with the model (*right*). It is seen that the two towers, which are 185 ft. tall and will carry the paraboloidal bowl, are almost complete. The towers are carried on six bogies running on a 17-ft. gauge railway track. Work will soon start on the bowl which will be erected in the air. The giant instrument should be operating by the end of this year or the beginning of next year.

CHEMICAL ENGINEERING IN EUROPE

One branch of technology which offers very promising careers in Britain is chemical engineering. There is at the present time an acute shortage of chemical engineers. This applies to Britain, and it is also true of Europe as a whole.

European deficiencies in the field of chemical engineering were brought out in the O.E.E.C. report published in 1952 with the somewhat misleading title of *Chemical Apparatus in the U.S.A.*, which dealt in fact not with laboratory apparatus but with the apparatus of large-scale industrial production. It was this report which prompted the European Productivity Agency of the Organisation for European Economic Co-operation to propose a conference to discuss what should be done to train more chemical engineers and to provide more research facilities in this field in European countries. The conference materialised as a stimulating and well-attended meeting in London in March which was organised by Britain's Institution of Chemical Engineers in conjuction with the D.S.I.R. and O.E.E.C.

Chemical engineering is of course the special kind of engineering associated with chemical production. As the ex-president of the Institution of Chemical Engineers, Sir Harold Hartley, has expressed it, "the original and still the most important field of chemical engineering is of course the chemical industry where the large modern plants with their automatic control of continuous processes are producing the substances—acids, alkalis, detergents, dyes, pharmaceuticals and fertilisers". World production of such items has increased by something like five to eight times in the past fifteen years. Other branches of industry require the services of the chemical engineer. Thus, petroleum refining and petroleum chemicals absorb about 10% of our chemical engineers, and quite a large number find employment in food-processing factories and the fermentation industry. Atomic energy developments have further increased the demand for this kind of technologist.

Chemical engineering is taught in the United Kingdom in the universities of Birmingham, Cambridge, Durham, Glasgow, Leeds, London and Manchester. There are two chairs of chemical engineering in London, one in Birmingham, one in Cambridge and one in Durham. The need for more training facilities has led to the founding of a new chair at University College, Swansea, and chairs are also being created at Manchester and Nottingham. There are also developments at Edinburgh and Sheffield. Full-time chemical engineering courses are provided by certain technical colleges.

The conference spent a whole day discussing the best ways of training chemical engineers, and the merits of undergraduate and postgraduate courses in chemical engineering were compared and suggestions made for their co-ordination. The principal British speakers included Prof. T. R. C. Fox of Cambridge, Prof. M. B. Donald of University College, London, and Prof. J. M. Coulson of King's College, University of Durham.

R. W. Blount, who is the Ministry of Education's staff inspector for chemical and metallurgical education, presented an interesting paper on the part-time course in chemical engineering. Similar courses have proved

very useful in the development of the mechanical and electrical branches of industrial engineering, and there is every reason to believe they will play an increasingly important role in the field of chemical engineering. In 1951 a scheme for the award of Higher National Certificates in chemical engineering was set up with the object of encouraging the provision of organised part-time courses, leading in the first instance to the award of a National Certificate, but so arranged that the successful student would have partly fulfilled the Institution of Chemical Engineers' examination requirements for Associate Membership. Mr. Blount explained the significance of the National Certificate system (which was inaugurated in the early 1920's) for the benefit of foreign visitors attending the conference, but some of the British present were obviously surprised to find how big is the output of National Certificate holders. Thus in 1954, 6211 ordinary National Certificates were awarded in mechanical engineering, and the figure for Higher National Certificates was 2860. In electrical engineering the figures were respectively 2833 and 1950.

The National Certificate scheme for chemical engineering is comparatively new, and has hardly caught on as yet. But it has great possibilities, and no less than twenty technical colleges provide approved courses for such part-time students in this subject.

One important session was devoted to discussion of the part played by the chemical engineer in bridging the gap between research and plant construction. So much has been heard about the importance of the pilot plant which intervenes between the perfecting of a laboratory process for preparing a chemical and the final large-scale plant that it came as something of a shock to hear men of great experience saying that the pilot plant is by no means indispensable. But obviously many members of the conference agreed with this view, whose strongest advocate was Sir Christopher Hinton, who is Managing Director of the Atomic Energy Authority's Industrial Group at Risley. His experiences in connexion with atomic energy developments justify his opinion. In the last eight years the urgency with which production has been required in Britain's atomic factories has been so great that generally there was no time for the construction of pilot plants. A case in point is the primary separation plant at the Windscale Factory, where irradiated rods are dissolved and the solution passed through a solvent extraction process to separate the fission products from the uranium and the uranium from the plutonium, was designed on the basis of laboratory work carried out on only 20 milligrams of plutonium. No complete pilot plant was built, and at the time when the design work was carried out the only chemical engineering research available was on some of the unit operations, where work had to be done to establish the necessary dimensions of these individual sections of the plant. In spite of this, the plant went into operation literally without a hitch, and this experience has been repeated in other atomic energy plants. Sir Christopher said that pre-war he doubted whether satisfactory plants could be designed without obtaining experience on pilot plants. Now he believes that the construction of pilot plants is not an unmixed blessing, in that there is not the same need to be very careful when designing a small pilot plant as there is with a full-scale plant. If one cuts out the pilot-plant stage, then the designer aims to achieve greater precision. This means that he faces bigger risks, but if his aim is true then there is a considerable saving of time and money.

A gratifying feature of the conference was the respectable position occupied by this country in chemical engineering. The quality of the training and work was thought by many European observers to have points in advance of American practice. It is of course the boast of this country that the true foundation of chemical engineering was the work of George E. Davis. He was a remarkable man, a consultant, alkali inspector and lecturer at Manchester Technical College, who proposed in 1880 to form a Society of Chemical Engineers. His proposal actually gave rise to the formation of the Society of Chemical Industry with Mr. Davis as first secretary. (The foundation of the Institution of Chemical Engineers did not materialise until much later—1923 to be exact.) His lectures were published as a book which was in fact the first textbook of chemical engineering. He had the vision to realise that the first stage in the development of a new branch of technology was mainly one of classification. From his idea that nearly all the work carried out in chemical works could be analysed into a series of physical processes sprang the concept of unit operations. This did not become effective until the twenties in the U.S.A. as the key to a new class of engineering studies.

But in considering national claims for priority, the international basis of all technologies should not be forgotten. Mr. Davis may have been a pioneer, but credit for the first clearing made of this particular territory should perhaps go to the Dutchman, Boerhaave. His influence lies behind the description of chemistry in the early 18th century given in *Chambers's Dictionary*.

> "The operations of *Chymistry* include all the changes produced in bodies by natural agents or instruments: viz. *decoction, infusion, exhalation, calcination, extraction, distillation, crystallisation,* etc."

That is coming pretty close to defining unit operations, and there were other writings of Boerhaave which nearly anticipated some of the modern definitions of chemical engineering. The 18th-century chemists were closely in touch with industrial developments. The Dutch are important in the chemical engineering field, and the graduates of the Delft school in particular have today a strong influence over the whole of Europe.

It may be that the conference will have wider results than the limited objects with which it was organised. The other Europeans have acknowledged the high standard and standing of this country and closer co-operation is inevitable. It will do the people here good if they are saved from the insularity which often accompanies success.

PENICILLIN'S DISCOVERER

The world at large retains its unreserved applause today for those scientists whose work saves lives or improves living conditions, and the editorials which the newspapers printed after Sir Alexander Fleming's death on March 11 reflected this attitude, focusing attention upon the fact that penicillin represents one discovery which has had no dark side to it. The name of Fleming is so closely linked with penicillin—which he discovered, named and suggested might be clinically valuable as an antiseptic—that it is easy to forget other important researches with which he was connected. Thus his discovery of the remarkable antibacterial enzyme lysozyme in 1922 was not only of considerable importance in itself. It must have stimulated his already deep interest in antiseptics and attuned his mind to appreciate the significance of the contaminated culture plate by which, as all the world now knows, the mould called *Penicillium notatum* introduced itself as the producer of the most valuable chemotherapeutic agents we possess. As a bacteriologist he made numerous original contributions, for example on the culture of *Bacillus influenzae*.

The discovery of penicillin may truly be said to have resulted from an accident—the contamination of a staphylococcal culture by a spore of *P. notatum*—but it was an accident whose meaning only a highly trained and alert mind could understand. What made the accident so vastly fruitful eventually was that Fleming had for years previously been keenly interested in methods of attacking bacteria. His whole previous career had in a sense prepared him to seize upon that one contamination—out of the great number that occur in even the most carefully regulated bacteriological laboratories—and single it out for further study.

As a young man he had had no thought for medicine and it was an older brother, who had qualified, who persuaded him into its study, and he entered St. Mary's Hospital Medical School. At once, however, it was clear that he had found his vocation. His career as a student was brilliant. Under the influence of Sir Almroth Wright he began to specialise in bacteriology, and thereafter the microscope was his principal research tool. In the first World War he worked in Wright's laboratory in France, and saw the inadequacies of some of the conventional antiseptics used for treating wounds. Returning with Wright to London at the end of the war he became lecturer in bacteriology at St. Mary's. Soon came his first major discovery—that of lysozyme, which he found in nasal secretions and subsequently in other body fluids. This work again gave him further valuable experience in the technique of studying substances with antibacterial properties.

Thus when Fleming's unique opportunity came in 1928 he was alert to seize it: "If my mind had not been in a reasonably perceptive state, I would not have paid any attention to it." He isolated the active mould from the contaminated plate and subcultured it in broth. He found that the filtered cultures, which he called penicillin, possessed the same kind of antibacterial effect as the mould itself had shown on the plate. He found that

Sir Alexander Fleming in his laboratory.

these crude filtrates had a low toxicity and might be used for local applications, for example in dressing infected wounds. He realised, however, that more detailed study—and in particular the assessment of its possibilities for attacking infections affecting the body as a whole—must depend upon purifying and concentrating the material. With others—notably Clutterbuck, Lovell and Raistrick of the London School of Hygiene and Tropical Medicine—he attempted to isolate penicillin, but its chemical instability defeated them and by about 1932 the work was put on one side, though not forgotten.

Subsequently the study of penicillin was taken up at Oxford by Florey and Chain, and a team of specialists which they gathered together, with results which are now well known. They purified penicillin, they demonstrated its unique properties for the treatment of general bacterial infections of many types, and—in its way a scarcely less difficult task—developed the process that could be used for its industrial production. This was developed on an ever-increasing scale, so that today penicillin is one of the greatest boons of mankind.

There were thus two perfectly distinct phases in the penicillin story. The first was its discovery by Fleming at St. Mary's; the second the full recognition of its qualities and its development as a drug for general medical use by Florey, Chain and their collaborators at Oxford. Clearly the two phases are complementary, and it would be very invidious to try now to apportion the credit between the two schools. Very rightly the Nobel Prize for Medicine in 1945 was awarded jointly to Chain, Fleming and Florey. In science, as in all other fields, to be the first to do something earns a distinction which no subsequent developments, however great, can diminish.

Recognition of the most remarkable properties of penicillin led to a torrent of research all over the world in the search for other antibiotics of medical value. Although some of the new discoveries resulting from these great and carefully planned research projects have found regular use, it is truly remarkable that none has yet proved comparable with penicillin, the fruit of chance.

SIR FREDERICK BRUNDRETT

CHAPMAN PINCHER

Science has brought about a revolution in military tactics and strategy. The subject of this biographical sketch is the leading British authority on the application of science in this field.

Among the most influential scientists in Britain today is Sir Frederick Brundrett, who is also one of the least-known to the general public. He holds the dual appointment of Chief Scientific Adviser to the Ministry of Defence and Chairman of the Defence Research Policy Committee. These titles cover a multitude of duties, many of them secret, which are all concerned with ensuring Britain's survival in any conflict in the immediate or foreseeable future.

As personal adviser to the Defence Minister, Sir Frederick is largely responsible for what amounts to briefing the Cabinet on the capabilities of new weapons and defensive equipments. His considered views are based on the frequent discussions held by the several Inter-Services Committees of which he is chairman or a leading member.

As Chairman of the Defence Research Policy Committee he is responsible for advising the Defence Minister and the Service Chiefs about the lines of scientific endeavour which are most likely to result in usable weapons in the future. He must also indicate the priorities which should be given to these lines so that the country's limited resources can be put to the best use.

In addition he must keep abreast of foreign weapons developments through Intelligence reports and help to estimate the extent to which such weapons increase the strength of our potential enemies.

Much of Sir Frederick's patient work on these lines was crystallised in the recent White Paper on Defence. The decisions revealed in the White Paper were of course political, but in formulating policy about modern weapons the politicians must rely largely on information and advice given by scientists, of whom Sir Frederick is in the most commanding position.

Success in such a post demands an unusual array of talents. The holder should be a "weapons man"—a scientist with real interest in weapons, which constitute a fascinating if distasteful field of research. He must have the type of mind which can range over an immense and constantly changing field and abstract the relevant developments. He must be a firm handler of committees yet have the type of personality which enables him to act as mediator between top-level men with differing views and retain their co-operation and respect. Above all, perhaps, he must have a reputation for integrity which convinces his colleagues that he will neither favour particular individuals and Services, nor ride his own hobby-horses at the nation's expense. The nation is fortunate in that Brundrett possesses all these qualities. In addition he has a phenomenal capacity for work.

He is not an eminent scientist in the sense that he has made important contributions to knowledge, but as his greatest predecessor, Sir Henry Tizard, proved, eminence in science is not a necessary qualification for the post, though a thorough grounding in scientific method is, of course, essential. Sir Frederick obtained this grounding through thirty-six years in Government defence research work.

After an outstanding scholastic career at Rossall and Cambridge, where he was a wrangler, he joined the Navy as a rating in 1916, but was soon given a scientific job in connexion with the development of wireless telegraphy. On demobilisation, he joined the Admiralty Signal School and remained in Admiralty employment until 1950. He did important mathematical work on, for example, communication with submerged submarines and the design of radio aerials, but the laboratory side of his work was quickly swamped by administrative duties for which he showed exceptional ability. He was responsible for organising the world-wide trials which led to the adoption of short-wave radio by the Navy, then considered a rather daring move.

Brundrett's main work during World War II was the recruiting and placing of scientists in experimental establishments serving the three Services. He was noted for his ability to cut through red tape; when, for instance, he was asked to find twelve scientists to fight the magnetic mine menace, he had them on the job within twenty-four hours. It was through this work that he acquired his enviable reputation for fairness. In the book *One Story of Radar*, A. P. Rowe, wartime chief of the Telecommunications Research Establishment at Malvern, wrote,„"The allocation of men to the different Ministries was largely in the hands of F. Brundrett at the Admiralty. This was a completely illogical arrangement but because of Brundrett's scrupulous fairness it worked well."

After the war Brundrett formulated the basic proposals on which the Royal Naval Scientific Service was built, and was put in charge of the Service in 1947. It was largely through his initiative while in that office that the Joint Services Electronics Research Laboratory was set up at Baldock. He was also largely responsible for starting up the fine National Institute of Oceanography at Wormley, Surrey.

In 1950 Brundrett transferred to the Ministry of Defence to help Sir Henry Tizard, who was then Chairman of the Defence Research Policy Committee and Scientific Adviser to the Defence Minister. This partnership worked admirably. Brundrett, who has always admired Tizard's immense ability, relieved him of much of the administrative work.

Tizard retired in 1952. He was succeeded by Sir John Cockcroft, and it was originally intended that the appointment should be full-time. Lord Cherwell opposed this view and urged that Sir John should remain

in control at Harwell as well as carrying out Tizard's former functions. Brundrett remained and deputised for Sir John during his frequent absences abroad.

When Cockcroft was made a Director of the Atomic Energy Authority in 1954, he relinquished his Defence Ministry appointments and was succeeded by Brundrett, who has carried the entire burden of the work since then with great success. Most of his achievements are obscured by security and will long remain so. Among those which can be mentioned are the reorganisation of the Scientific Intelligence Service (which I described in DISCOVERY, February 1955, pp. 65–9), and much of the "operational thinking" behind the White Paper on Defence.

The soundness of Brundrett's "operational thinking" is becoming increasingly appreciated in defence circles. Without clear "operational thinking" weapons may be devised which look impressive but are not effective in use. The German V2 was an example of bad "operational thinking". An enormous effort went into producing a most ingenious weapon which had practically no effect on the course of the war. The huge atomic cannon devised by the Americans would seem to fall into this category, and it is significant that the British Army is not to be equipped with anything like it.

Sir Henry Tizard developed a new understanding between the scientists and the fighting men during his years of office. Before his day Service chiefs tended to regard the scientists as cranks who produced ideas which were hare-brained and unrealistic. Tizard convinced the Staff Chiefs that modern wars cannot be won without continuous scientific invention. Brundrett has fortified this view and convinced them that continuous scientific research is also essential to *prevent* wars. He was among the first to foresee the inevitability of Britain's dependence on the deterrent effect of offensive weapons. Like Tizard, he seems to have developed the knack of backing the right hunches.

The high standing of his reputation with the Americans was demonstrated by the esteem with which he was received during a tour of U.S. guided missile establishments last year.

Sir Frederick has so many outside interests that they might seem to conflict with his work because of the time they must consume. In fact they have proved to be a considerable help. His large farming interests have made him financially independent of his Civil Service salary, so he can always speak his mind without the fear that he might lose his livelihood as a result of opposing powerful interests.

Sir Frederick's curiosity in animal breeding was aroused as a result of his mathematical study of Mendel's laws of inheritance. In 1920 he started experimenting with poultry, and eventually built up in partnership with his brother one of the biggest pedigree poultry breeding establishments in Britain. They now own a large herd of Redpoll cattle, and many pigs and poultry on their two farms near Emsworth, Hants.

He also formed a large co-operative egg-distributing organisation that markets more than twenty million eggs a year for its farmer members. Of this concern he is now governing director. He is also Chairman of the Agricultural Co-operative Association.

SIR FREDERICK BRUNDRETT

In addition to all this time-consuming work he has taken on the job of honorary scientific adviser to the Ministry of Transport and Civil Aviation, and is a member of the Colonial Office Committee for Agricultural Co-operation in the Colonies.

He says he does not mind how hard he drives himself during the week so long as he can farm on Sundays.

Brundrett's energy is such that he greatly regrets he is no longer young enough to play games as well. A sportsman with a fine eye for ball-games, he captained Hampshire at hockey for twelve years, and regularly made five hundred runs and took fifty wickets a season in club cricket.

Even these interests have contributed to Brundrett's success in his present post. Most of his games were played in the Portsmouth area with team-mates who are now highly placed in the Navy, Admiralty, or other defence departments.

Even his odd but useful service as Agricultural Adviser to Whale Island has brought its quota of friends some of whom are now in key positions.

In short, Sir Frederick Brundrett is a dedicated man, superbly equipped by endowment, training and circumstance for his vital post and it is to be hoped that he will long remain in it.

A BRITAIN WITHOUT RABBITS?

H. N. SOUTHERN, M.A.

The balance of nature in many areas of Britain is considerably altered as a result of the spread of myxomatosis. In this article H. N. Southern of the Bureau of Animal Population discusses some of the ecological consequences of the reduction of the rabbit population.

There were people who said that rabbit myxomatosis would not spread in Great Britain when it gained a foothold here in the autumn of 1953. By now the disease has given its own answer, and much ink has been spilled to prove that its encroachment has been one of the greatest crimes ever allowed, or one of the greatest benefits bestowed on us.

To turn to facts, the Second Report of the Myxomatosis Advisory Committee, published in 1955 by H.M. Stationery Office, is a remarkable document. It is admirably brief and contains a map which gives the most careful and detailed picture we yet possess of the progress of the disease in any country. The really striking information it conveys, however, is the astonishing way in which the infection gathered speed as the autumn verged into winter. The records on the map between September 30 and December 31, 1954, well outnumber all the previous ones, so that by now practically the whole of the south of England and Wales south of a curve running from the Dee down to Warwickshire and up again to the Wash, is solidly affected. The design of the map shows very clearly how separate foci developed during the summer months (in Kent & Sussex, East Anglia, Devon & Cornwall, Gloucestershire, north, south-west and central Wales and Lincolnshire) and how these spread and coalesced during the autumn. Similar focal points have appeared throughout the north of Britain, and it is certain that these will expand in the same way during 1955.

In areas where myxomatosis has flared up and died away the surviving rabbits are few and far between. The death rate, as in Australia, has been 99% or more. As an example which came to my own notice, a woodland estate of 1000 acres belonging to Oxford University at Wytham, Berkshire, on which 1000–2000 rabbits were killed every year, could show only two or three tracks during the recent snows.

Now we have to face the repercussions of this explosion. I do not propose to deal here with the problems of how long it will be before rabbit populations will build up again, and how near they will approach to their previous levels. The answers will depend on many things, not least of which will be the attitude the country finally adopts to the disease. What is certain is that we shall have 3–5 years with a rabbit population smaller than at any time during the last few centuries. It is worth trying to assess the probable effect of this upon populations of other animals and upon vegetation.

In passing it is as well to emphasise the highly specific nature of myxomatosis. During the whole course of the outbreaks in France and Great Britain up to now the only animals other than rabbits which have been proved susceptible have been a handful of hares. When we consider the great number of hares which must have been exposed to infection and their close relationship to rabbits we can only be surprised at their resistance. Certainly it is evidence for the extreme improbability of more remotely related animals (e.g. dogs, farm stock and even man have been canvassed by alarmists as susceptible) ever suffering from myxoma virus. This confirms the extensive and careful tests made by the Australians on many species of animals before they released the disease, none of which showed the slightest symptoms.

From the purely scientific point of view myxomatosis has performed an ecological experiment for us on the largest scale. It is fortunate that in the last 25 years the study of the vital statistics of wild animal populations has taken its place as a fundamental part of ecology. Work already done gives a basis of method for measuring the "turnover" of populations and it is possible to do rather more than make intelligent guesses about what will happen. On the other hand these pioneer investigations have also impressed us with the extreme complexity of the subject and have taught us a proper humility in approaching it.

VITAL STATISTICS OF THE RABBIT

We may glance briefly at the population research already done upon the wild rabbit. Before the war, when rabbits in the agricultural lowlands of England were very numerous, I myself (in 1938–42) studied the population of a warren by the method of live-trapping, marking and releasing and found that a breeding population of some 70 adults living on half an acre of warren (i.e. excluding their feeding grounds, which I could not measure exactly) produced something like 280 *weaned* young during one season. If this population was stationary from year to year, this means an annual mortality of 80%, neglecting that in the nest, so the turnover is very high and obviously a fair population of predators besides man can be supported. On the other hand the maximum density on the warren at any one time did not exceed 163 rabbits and this is the important figure when we consider the effect on the vegetation.

Unfortunately there is no published information on the average amount of herbage a wild rabbit will eat per day. A large tame rabbit may eat as much as 2 lb. and, even allowing for the difference in size, it becomes clear that the rabbit is an efficient mowing machine. Some further field research was done after the war in west Wales, a district notorious for its rabbit "farms", by Miss W. M. Phillips. She carried out marking experiments to estimate the numbers and turnover in the population and at the same time arranged plots of sown grassland, half of which were rabbit grazed and half

protected. On the 114 acres which she studied rabbits varied from a spring minimum of 500 to a summer maximum of about 2000 despite the fact that routine operations by rabbit trappers (supposed to control the rabbits) were continued during her work.

On the experimental plots the yield of herbage which was protected from rabbits ranged from twice to eight times as much as on the grazed areas according to season (W. M. Phillips, 1953): furthermore the rabbits also changed the botanical composition of the sward. If the components of the grazed plots are expressed as percentages of the ungrazed, we have the following figures: sown grasses 9, clover 20, unsown grasses 57, "weeds" 371, and bracken 120. This gives us a preliminary glimpse of what the removal of rabbits would mean to grassland in terms of quantity and quality.

H. V. Thompson and C. J. Armour have also been making similar investigations, but only a preliminary summary of some of their results has been published (H. V. Thompson, 1951). They mention that the live-weight increase of sheep over 7 months was 800 lb. on rabbit-free plots compared with 650 lb. on rabbit-grazed plots.

These measurements of population numbers and of the effect of grazing on swards show that even if rabbits are only moderately abundant (say a September level of only 6–8 per acre), this means that they are by far the most important converters of vegetation into flesh of any of our wild animals, since some 20 lb. of rabbits are being maintained per acre compared with probably less than 2 lb. of the next most abundant animals—wood mice and voles. Rabbits, therefore, since they were introduced into Britain in the 12th century, have risen to being a "key industry" in the dynamics of our animal communities.

GRASSLAND AND THE RABBIT'S DISAPPEARANCE

On grassland the effect of the rabbit's disappearance will mean an immediate, big increase in the quantity of vegetation. If this grass is to be used, it will be vital to replace the grazing pressure and/or increase the hay crop. If not, the grass will either grow old and useless, or it will stimulate populations of alternative natural grazers, such as the short-tailed vole. On marginal grasslands, especially those devoted to young forestry plantations, this vole sometimes increases to plague proportions and does widespread damage to young trees. An interesting point is that these plagues are commonest in areas fenced off from rabbits, to grow trees. If the whole of the country's rough grasslands become "fenced" by the death of the rabbits, then widespread outbreaks of voles, such as occurred in the years 1952–4 in the Carron Valley, Stirlingshire, may become a commonplace.

But the changes begun by the absence of rabbits will be qualitative as well as quantitative. Close grazing favours the persistence of a few species that can flower and vegetate at a height of 1–2 centimetres. Thus on acid ground especially, the herbage becomes impoverished and grasses of the genera *Agrostis* and *Festuca* come to predominate to the exclusion of ling (*Calluna*), for example. Many of our heather moorlands have been transformed into rough grass by rabbits, and such areas will presumably revert to their previous state, wherever the more delicate plants have not been killed out.

Similarly in woodland the presence of rabbits tends to depress the abundance of dicotyledonous plants generally, including the natural regeneration of forest trees, and promotes a sparse ground layer of grasses. Initially, at any rate, the loss of rabbits will allow the growth of a much richer ground layer and encourage a lusty crop of saplings. It has been a depressing sight in many of our forests to note no single tree less than 100 years of age.

It would be fortunate if matters were as simple as this, but the many centuries, during which the rabbit has settled down with us concurrently with the clearing of climax forest, have allowed it to take on a rôle in maintaining the delicately balanced sub-climaxes, which have replaced the forest. It was grazing by sheep and rabbits that maintained the pastoral uplands of Britain in a state which enriched us with a lucrative wool trade. In the last 50 years the pressure of sheep has been lifted and the rabbits have increased. This has kept the downlands open, but exposed them to the advance of bracken and such weeds as ragwort and nettles which colonise the soil disturbed by rabbit scratchings and burrowings. This advancing front may be halted now that rabbits are going, though it cannot be pushed back except by radical and expensive measures, but there are other more menacing dangers. The chalk and limestone uplands are peculiarly susceptible to be over-run by useless

FIG. 1. Rabbit in intermediate stage of myxomatosis. This animal was quite blind and deaf, but continued feeding the whole time it was watched.

grasses (useless both from the agricultural and naturalist's points of view) such as the upright brome grass (*Bromus erectus*) and the tor-grass (*Brachypodium pinnatum*). Sheep and rabbits can keep these in check; so can rabbits alone if they are dense enough to make the sward poor anyway. But without either of them a sea of pallid tor-grass is likely to engulf the downs, unless some spray or other treatment is devised to replace the repressive effect of the rabbit.

Furthermore, many of our rarest and most attractive plants, including some of the orchids, flourish on a low sward, and the lifting of grazing pressure may well eliminate them. An excellent example of this process is seen at Uffington Castle by the White Horse Hill. The ramparts and enclosure of this earthwork are now a national monument, sheep are excluded and the surrounding land is so intensively cultivated that rabbits were scarce even before myxomatosis arrived. The result is a sea of deep, tussocky grasses where once the old records state that the man orchid and the fly orchid were found. The disappearance of the rabbit will, therefore, worry the conservationist as well as the farmer.

But, if the rabbit is a key animal in modifying and controlling its vegetational surroundings, it must have an equally important effect on the levels above it in the food chain. It has always been fair game for many other beasts of prey than man. What will be the effect (*a*) on the animals and birds that eat rabbits and (*b*) upon the alternative prey species of these predators? Let us glance briefly at the tangle of inter-relationships which surrounds the rabbit in the ordinary lowland English countryside. The situation can best be depicted in the diagram (Fig. 4). The arrows point in each case from the prey to the predator that eats it and dotted arrows indicate a secondary, or less preferred, prey.

These complex food relationships must be regarded as accurate only in a general way. In the first place detailed studies for each predator are only accumulating gradually; secondly, those that have been published—e.g. the papers on the tawny owl (Southern, 1954), the little owl (Hibbert-Ware, 1937–8) and the fox (Southern & Watson, 1941) show us how greatly the diets vary in time and place.

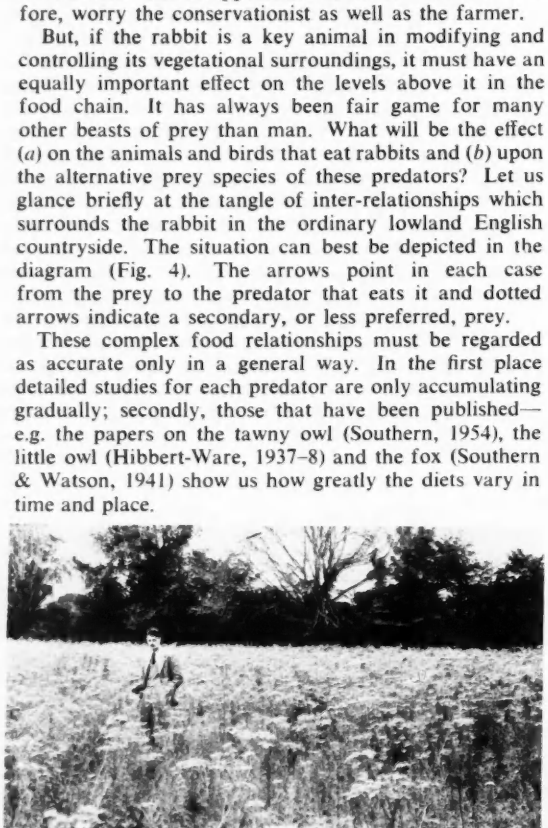
One might logically suppose that an increase, for instance, in the number of stoats must result simply in a decrease of its main prey, the rabbit. But, apart from the fact that a decrease in prey may automatically reduce the predator after a time lag (a closed food relationship between two species should produce staggered and regular fluctuations known to ecologists as "Lotka-Volterra oscillations") the many cross connexions in the diagram show that there is no point in the nexus where an initial disturbance may not be felt. Thus in the case of the stoat-rabbit example just mentioned a chain of alterations might well result as follows: more stoats will mean less rabbits and therefore less buzzards; this in turn may stimulate mice and voles, which would increase the kestrel, and this again might bear heavily on small birds; and so on. The cross connexions are so numerous that a moderate change at any point will almost certainly be buffered close to its origin.

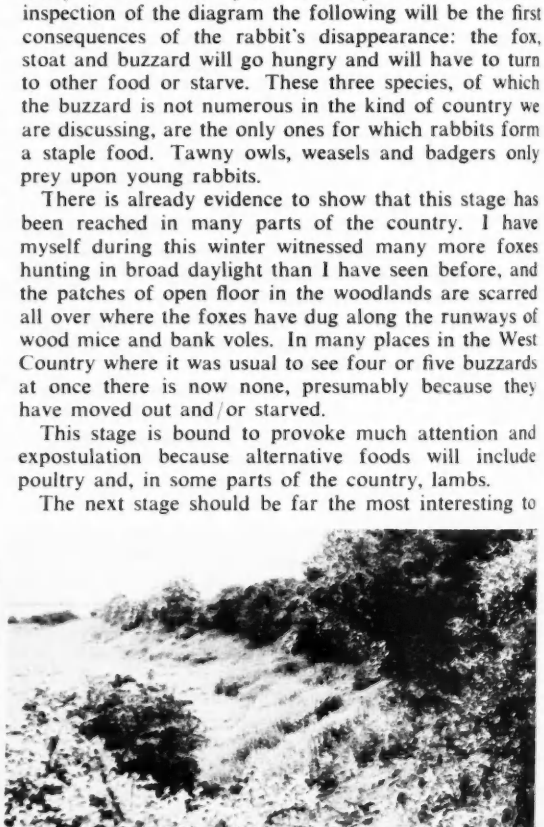
But the near elimination of a key industry like the rabbit is another matter. Such a fundamental change is likely to shake the system severely. From a careful inspection of the diagram the following will be the first consequences of the rabbit's disappearance: the fox, stoat and buzzard will go hungry and will have to turn to other food or starve. These three species, of which the buzzard is not numerous in the kind of country we are discussing, are the only ones for which rabbits form a staple food. Tawny owls, weasels and badgers only prey upon young rabbits.

There is already evidence to show that this stage has been reached in many parts of the country. I have myself during this winter witnessed many more foxes hunting in broad daylight than I have seen before, and the patches of open floor in the woodlands are scarred all over where the foxes have dug along the runways of wood mice and bank voles. In many places in the West Country where it was usual to see four or five buzzards at once there is now none, presumably because they have moved out and/or starved.

This stage is bound to provoke much attention and expostulation because alternative foods will include poultry and, in some parts of the country, lambs.

The next stage should be far the most interesting to





Changes in vegetation follow a reduction in rabbit population, or an increase. FIG. 2 (*left*) shows a handsome crop of ragwort covering rabbit-infested pasture. FIG. 3 (*right*). Here nettles have invaded the soil excavated by burrowing rabbits.

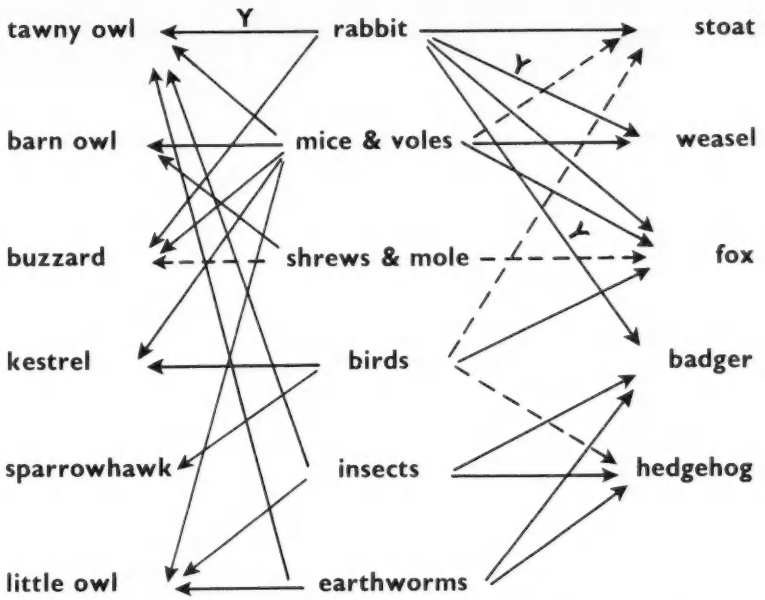


FIG. 4. This diagram indicates the complexity of the food chains centring round rabbits and small mammals. The centre column lists the main groups of animals preyed upon; the left-hand column lists birds of prey and the right-hand beasts of prey. Arrows drawn with uninterrupted lines indicate that the prey constitutes a major item in the food of the predator concerned; interrupted lines show secondary items. A "Y" associated with an arrow means that the predator takes only the young of the prey.

the ecologist. Other things being equal, the effect of a group of predators sharing out a reduced total of food should mean first a reduction in their own numbers, then a jostling down to a new equilibrium in which predators and prey will possibly co-exist in reduced numbers. This may well be a return to an equilibrium which has not been known in this country for 6–7 centuries.

But this will only take place if the predators are actually controlling the numbers of the prey, and here "controlling" is used in the specialised sense of just eliminating the surplus population of prey each year, however large that surplus may be. Hence the control is mutual and the populations of both tend to oscillate through reciprocal readjustments around fairly stable mean values. We have not yet sufficient data to show how many of our wild animals are regulated in this way, though it now seems probable that some of them are.

Alternatively quite different results could be produced if some of the prey populations are regulated by other factors than predation. D. H. Chitty (1938) has shown that short-tailed voles in young forestry plantations are preyed upon only to a small degree by their main predator, the short-eared owl. It seems much more probable that their numbers are geared to their food supply and above certain levels are influenced by the ill-effects of crowding.

Clearly what rabbits do not eat will be available for other herbivores and, if the numbers of the small rodents are related to their food supply, presumably they will increase and will be able to support some of the predators which have been left in the lurch by the rabbit. This would allow animal communities to remain in much the same balance as before, except that the species in the "primary producer" level would change.

I think it is most probable that the result will be a mixture of both processes. If this is so, the ecological implications may be extremely important because such a result might show which of our herbivorous animals are regulated in their numbers by their food supply. The experiment performed out of the blue by myxomatosis is on so vast a scale that it may answer questions which only generations of patient work by other methods could disentangle.

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THE ORIGIN AND EVOLUTION OF COAL

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The different properties of coal which are so important to all coal users, are ascribed to differences in the plant materials from which it has evolved and the physical and chemical changes which have occurred during a geological history of many million years. This article, by a geologist, gives an account of the processes involved in coal formation. It explains the classification of the different coal "types", and the transformation of peat into four main "groups"—brown coals or lignites, sub-bituminous, bituminous and anthracite coals. Passing through the series there is a steady decrease in the content of volatiles and an increase in carbon, until high-grade anthracites may contain as much as 95% carbon. There is a consequent variation in those properties which are of interest to coal users, in particular the industrial consumers who are concerned with the mineral's coking powers and its suitability for oil and gas production.

Although we appreciate the vitally important role which coal plays in our highly industrial community, and have some knowledge of its many applications, we rarely give much thought to the origin and evolution of this complex organic material. We recognise the diversity of form assumed by coal, and are able to exploit the properties of each variety to our greatest advantage, but the significance of the variations, in terms of fundamental constituents, is seldom considered.

A brief account of the more important stages in the history of coal may thus present a clearer picture of the numerous coal varieties, the conditions under which they were formed, and the factors which have led to their preservation. Such an account must necessarily avoid the controversial issues and highly specialised problems which have arisen from the extensive research into the nature of coal carried out during recent years.

Coal has been defined as *"a combustible rock which had its origin in the accumulation and partial decomposition of vegetation"*. This concise definition of Stutzer and Noe forms the foundation to the history of coal formation which we are to follow.

Given suitable conditions for the accumulation and preservation of their remains, plants have contributed the essential ingredients to coal since its first appearance in the geological record. Little is known about the plant life which existed during the early periods of geological history, but by Carboniferous times, nearly 300 million years ago, the flora had become highly evolved. The vegetation of this period included giant club-mosses, luxuriant tree-ferns and horse-tails, seed-bearing plants with a fern-like foliage, and extinct forerunners of modern conifers. A pictorial reconstruction of a typical Carboniferous "Coal Measures" forest is shown in Fig. 1. Although great changes have taken place in the flora since Carboniferous times—few modern species show close affinities with ancestral forms—the structure and chemical composition of plants have remained essentially the same. Microscopic examination of recognisable plant remains from the Carboniferous and succeeding periods has confirmed the presence of organs and tissues comparable with those of present-day vegetation.

In their normal processes of metabolism plants synthesise their component tissues from atmospheric carbon dioxide and mineral-charged waters from the soil. The complex compounds which make up these plant tissues are carbohydrates, such as cellulose, lignin, starches and sugars, together with proteins, fats, oils, resins and waxes. The carbohydrates—which form a high proportion of most plant tissues—consist of carbon, hydrogen and oxygen, whereas the resins, oils and allied substances are compounds of carbon and hydrogen with little or no oxygen. These hydrocarbon-rich compounds are important constituents of certain plant organs which require special protection from desiccation and physical damage; the waxy cuticle of leaf surfaces, the fatty substances of spore cases and pollen grains, the oil in seeds, and the resinous secretions found in woody tissue, all serve a protective function in being resistant to decay.

An accumulation of these hydrocarbon-rich plant fragments will thus differ greatly in chemical constitution from those deposits of general plant debris. The chemical composition of the plant remains—ranging between essentially carbohydrate and essentially hydrocarbon—and the varying proportions in which these constituents accumulate, are the most important factors determining the inherent character of the coals subsequently formed.

THE BIOCHEMICAL DECOMPOSITION OF THE PLANT CONSTITUENTS

Under normal atmospheric conditions plants will decay and disintegrate completely, yielding such substances as carbon dioxide and water. Fungi and bacteria are chiefly responsible for this decomposition, anaerobic bacteria being particularly effective because of their ability to extract oxygen from the plant tissue itself and to their consequent independence of atmospheric oxygen.

Decomposition is arrested when the activity of micro-organisms is brought to an end by toxic concentrations of their waste products. At this stage some of the original plant material will have been destroyed, and new chemical compounds formed. The precise nature of these changes will obviously depend on the original material and the environment during decomposition, but it is possible to distinguish two distinct processes of biochemical decay—"peat-formation" and "putrefaction".

PEAT-FORMATION

The process of peat-formation involves the accumulation of plant debris on the site of growth, under conditions which only admit small quantities of atmospheric oxygen. The debris is saturated by stagnant water, which allows sufficient aeration for restricted decomposition to take place. Fresh plant growth at the surface continually adds material to the slowly decomposing

FIG. 1. An impression of a forest swamp during the chief coal-forming period (Carboniferous), about 250 million years ago. A photograph of the diorama exhibited in the Geological Museum, South Kensington, London. (*Crown copyright.*)

humic debris, which gradually becomes compressed and transformed to a dark brown or black peat. Much of the component plant tissue remains clearly distinguishable, although the degree of decomposition will ultimately depend on the duration of micro-organism activity. In general, the substances which bind the tissues of the plant are destroyed, the individual tissues begin to disintegrate, and some of their constituents are broken down to simpler compounds. Proteins, sugars and starches are subjected to bacterial fermentation, and together with compounds formed by the incomplete reduction of the more resistant cellulose and lignin give rise to the dark-brown colloidal liquids which permeate the undecomposed debris. The exact nature of the degradation products is not clearly understood, but amongst the compounds recognised are aliphatic acids, humic acids, alcohols and aldehydes. The formation of these compounds is accompanied by evolution of such gases as carbon dioxide, methane and hydrogen, all of which escape to the atmosphere.

The chief effects of the biochemical degradation of plant material are summarised in Table 1. It will be seen that the formation of peat involves a steady increase in the proportion of compounds rich in carbon, brought about by a continual loss of volatile compounds containing substantial quantities of oxygen. The gain in nitrogen may be due to the activity and remains of micro-organisms.

PUTREFACTION

The process of putrefaction takes place in deeper stagnant waters, where the remains of minute organisms and unicellular algae, mingled with spores, pollen grains and finely comminuted wind-blown plant fragments, accumulate in the almost complete absence of air. Small quantities of finely-divided inorganic mud are also deposited and form, together with the organic remains, a slimy sediment known as "sapropel". On consolidation, sapropel becomes hard and exceedingly tough. Compared with peat it contains a higher proportion of hydrocarbon-rich compounds, owing to the concentration of spores and small organisms which remain unaffected by chemical or bacterial activity. The decomposition, or "putrefaction" of the less resistant plant fragments amounts to a slow distillation process, whereby methane, hydrogen and other gases are evolved.

TABLE 1. CHEMICAL ANALYSES OF PLANT SUBSTANCES AND PEAT*
(*calculated on an ash-free basis*)

Substance	Composition			
	Carbon	Hydrogen	Oxygen	Nitrogen
	%	%	%	%
Cellulose: *calculated from formula*	44·53	6·22	49·35	—
Wood: *average of 75 samples*	49·68	6·16	43·75	0·41
Brown peat	50·86	5·80	42·57	0·77
Black peat	59·70	5·70	33·04	1·56

* Based on information from *Data of Geochemistry* by F. W. Clarke, 1920.

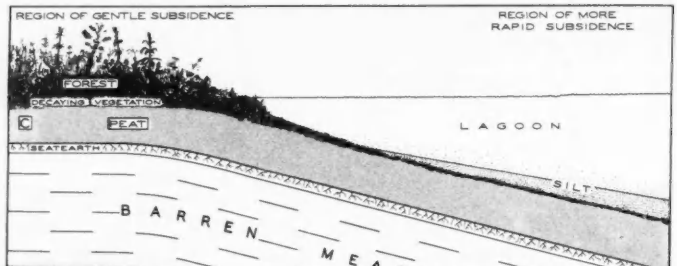


FIG. 2. A diagram illustrating the formation of peat and lignite: (A) lignitic coal representing an early stage of peat transformation; (B) consolidated peat; (C) freshly accumulated peat. (*Crown copyright.*)

There is no fixed boundary between the humic and sapropelic derivatives of biochemical decomposition, and although fundamental differences are apparent in the two extremes, all possible gradations are traceable from one to the other. It must be stressed that the final composition of the coal-forming deposit is controlled by three main factors: the variation in chemical composition of the plant constituents, the proportion of these constituents and the conditions which govern their accumulation.

THE INFLUENCE OF ENVIRONMENT ON THE DEPOSITION OF COAL-FORMING SEDIMENTS

The formation of peat and sapropel from plant debris is controlled by climatic factors and by those geological processes which lead to the deposition and preservation of inorganic sediments.

The most suitable environment for the accumulation of coal-forming peat is afforded by flat, low-lying ground, transformed into swamps by the restricted movement of surface water. Extensive, poorly drained coastal areas, forming deltas and estuaries of sluggish rivers, are ideal for the growth of plants and the accumulation of their remains under swamp-like conditions. A slow depression of the earth's crust in these regions counterbalances the increasing thickness of plant debris. However, the balance between subsidence and peat accumulation is not always exact; changes in the water-level of the swamps cause the termination of peat formation and may lead to the deposition of other types of sediment. Flooding of the swamps by fluvial or marine waters may introduce inorganic sands and muds, derived by erosion from neighbouring land surfaces. A substantial lowering of the water-level in the swamp may expose the previously accumulated peat to the agents of erosion and cause the removal of the entire deposit. A slow oscillation of the water-level, in conjunction with a general regional subsidence, may give rise to a considerable thickness of alternating layers of peat and "barren" sediments. With the retreat of the invading waters, after a period of barren sedimentation, the emerging land surfaces rapidly re-acquire a cover of vegetation and conditions for the formation of peat are again resumed (see Fig. 2).

The beds of peat usually rest upon sediments representing the soil surface in which the initial swamp vegetation rooted itself. These ancient soils, leached of alkalis by plant growth, and still containing traces of plant roots, may be recognised in the "seat-earths" which underlie coal seams at the present day.

In those parts of the swamp where the water is too deep for land plants to take root, aquatic plants and animals flourish, and contribute their remains to the sapropelic deposits. These deposits may eventually accumulate to sufficient thickness for swamp and terrestrial plants to establish themselves, and normal peat formation to commence. On the other hand, sapropelic deposits are sometimes overlain by sands and muds, which represent incursions of sediment-bearing currents of water into the stagnant pools and swampy lagoons. These strong currents may also remove parts of previously formed organic deposits; their activity is shown by the deeply scoured channels, filled with inorganic sediments, which are found in the "roofs" of many coal seams.

Climatic conditions promoting rapid and luxuriant growth of vegetation are most favourable for the formation of peat and sapropel. Equable temperatures, together with ample sunshine and moisture, are essential for such growth to take place. In order to maintain the wet substratum of swamps over extensive areas, precipitation has to be sufficient and well distributed: a too heavy rainfall leads to the dispersion of the organic debris, more extensive decay of constituents, and the removal of decomposition products. In general, a warm and humid climate, comparable with the temperate and sub-tropical types prevailing at the present day, would seem to be most suitable for the accumulation of coal-forming material.

THE PROCESS OF COALIFICATION AND THE COAL TYPES

The *biochemical* decomposition of accumulated plant remains comes to an end with the cessation of bacterial activity. At this stage the formation of peat and sapropel has been completed, and their transformation into coal is brought about by changes of a *physico-chemical* nature. The course of these changes, and the factors responsible for them, are not so well established as are the stages of biochemical decomposition. However, as the deposits of peat and sapropel are gradually buried beneath increasing thicknesses of younger sediments, the effects of rising pressure and temperature become manifest.

Under the influence of rising pressure and temperature, peat is compressed, and considerably reduced in volume by expulsion of water and volatile compounds containing oxygen. The progressive enrichment of carbon continues, and the peat gradually acquires the solidity, colour and chemical constitution of true humic coal. Sapropelic deposits, containing a rich concentration of hydrocarbons and only little oxygen, show a less pronounced rise in the ratio of carbon to oxygen during the process of coalification.

THE HUMIC COALS

The familiar humic coals are characterised by bands of "bright" and "dull" constituents, which are quite distinct in their physical properties and chemical composition, and reflect differences in the plant debris from which they have been derived. The term *clarain* has been applied to the type of soft humic coal which presents a shiny-black, well-laminated appearance, and is largely composed of "bright" constituents. The hard and almost lustreless "dull" coal, which shows no pronounced lamination or cleavage, is known as *durain*.

Clarain. Clarain constitutes a major part of the domestic "house" coal with which all of us are well acquainted. A close examination of typical clarain (see Figs. 3 and 4) reveals the presence of discrete laminae of uniformly brilliant black *vitrinite*, associated with minor quantities of a dull black material, known as *micrinite*. Vitrinite represents partly decayed bark and woody tissue, which have been completely impregnated by liquid decomposition products, and transformed into a hardened gel during peat-formation. Micrinite, derived from finely comminuted plant debris which often includes spores, leaf cuticles and resin bodies, is more variable in composition than vitrinite. A subordinate component of clarain is the powdery, black mineral-charcoal, described as *fusinite*, which occurs as thin irregular bands and lenticles, or as disseminations in the micrinite. It is claimed that fusinite originated through the decay of vegetable debris under certain conditions, provided by a direct contact with the atmosphere, which would allow a rapid loss of volatile matter. The subsequent preservation of the more resistant cellular tissue, without liquid impregnation, gave rise to the soft, charcoal-like fusinite.

The banded nature of typical clarain may be ascribed to the fluctuating conditions which prevailed during the accumulation of the plant debris, and to consequent variations in the debris itself. Whenever accumulating peat deposits were partially inundated by shallow water, conditions would become more suitable for the formation of durain.

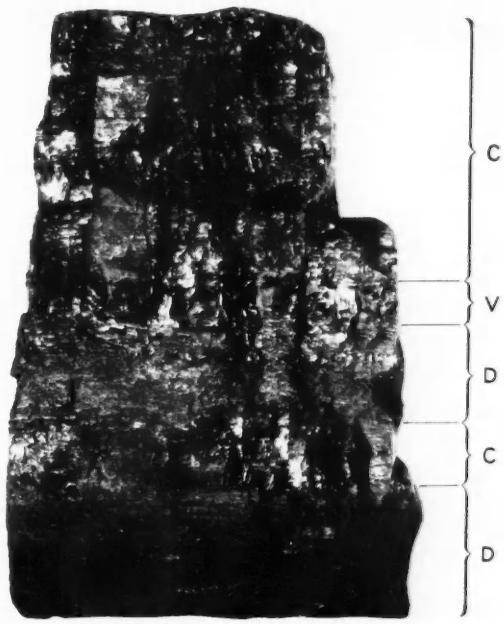


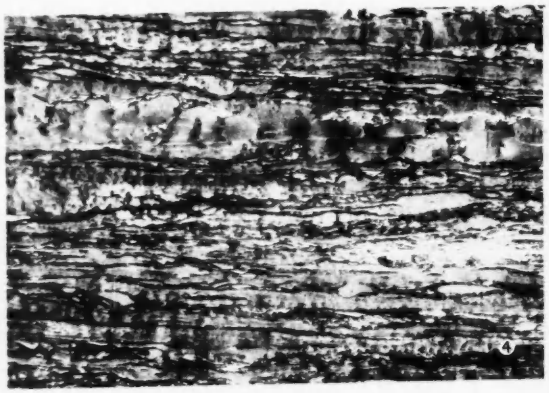
FIG. 3. Typical humic coal, showing layers of clarain (C), durain (D), and a prominent band of vitrinite (V).

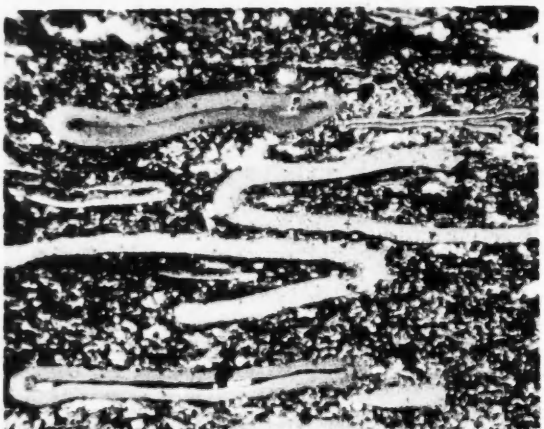
Durain. The characteristic features of durain are greater hardness, lustreless appearance and absence of prominent banding. Micrinite and fusinite are the two principal components of durain; they effectively mask the subordinate and shred-like bands of vitrinite. The micrinite usually contains a small quantity of inorganic mud which is intimately mixed with the fragmentary plant remains and finely divided fusinite. Spores, resin bodies and cuticles are commonly abundant in some durains, but others may be completely devoid of these hydrocarbon-rich constituents, and consequently show considerable differences in chemical composition.

There is little doubt, therefore, that durain is a coalified sediment of fine plant debris, inorganic mud and fragments of earlier-formed peat, originally deposited under conditions similar to those which control the formation of sapropel. Durain may thus be regarded as a type of coal falling between the sapropelic and humic varieties in appearance and composition.

SAPROPELIC COALS

The coals derived from sapropelic sediments are not so widely distributed as the humic varieties. They are typically dark-brown to black in colour and possess a dull, greasy lustre. The homogeneous nature and toughness of these coals gives rise to a well-developed conchoidal fracture.





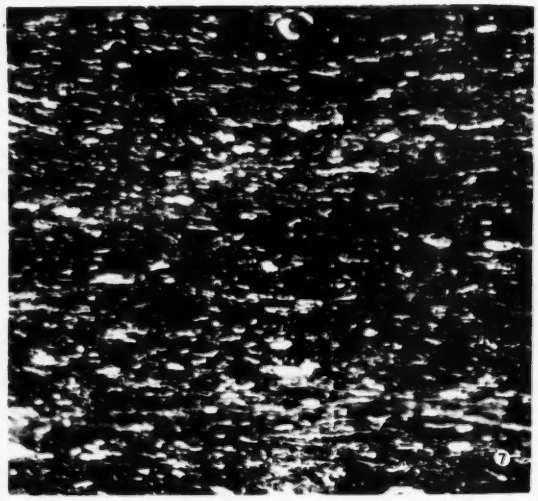


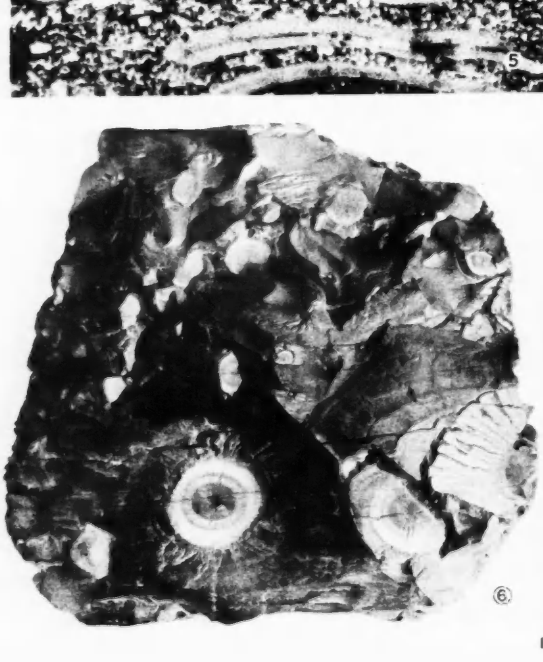
FIG. 4. Photomicrograph of clarain, showing thin bands of vitrinite, fragments of cuticle and resin bodies. ×82.

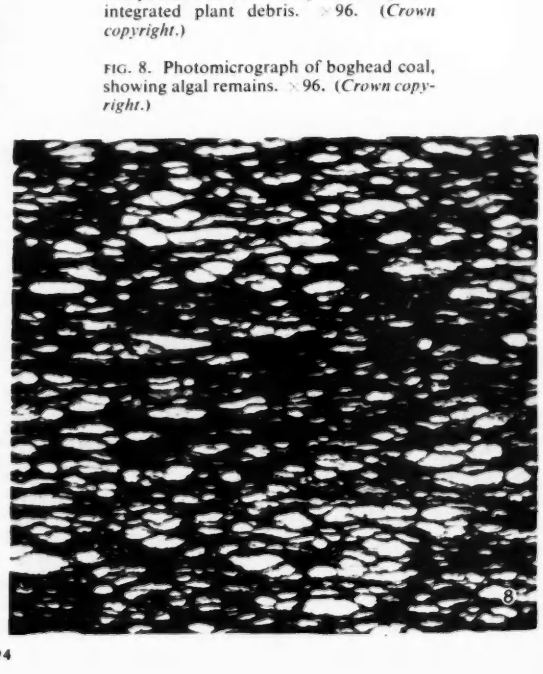
FIG. 5. Photomicrograph of durain, showing spores and leaf cuticles in a groundmass of micrinite and fusinite. ×56. (*Crown copyright.*)

FIG. 6. Cannel coal, showing the typical conchoidal fracture surfaces. (*Crown copyright.*)

FIG. 7. Photomicrograph of a cannel coal composed almost entirely of finely disintegrated plant debris. ×96. (*Crown copyright.*)

FIG. 8. Photomicrograph of boghead coal, showing algal remains. ×96. (*Crown copyright.*)





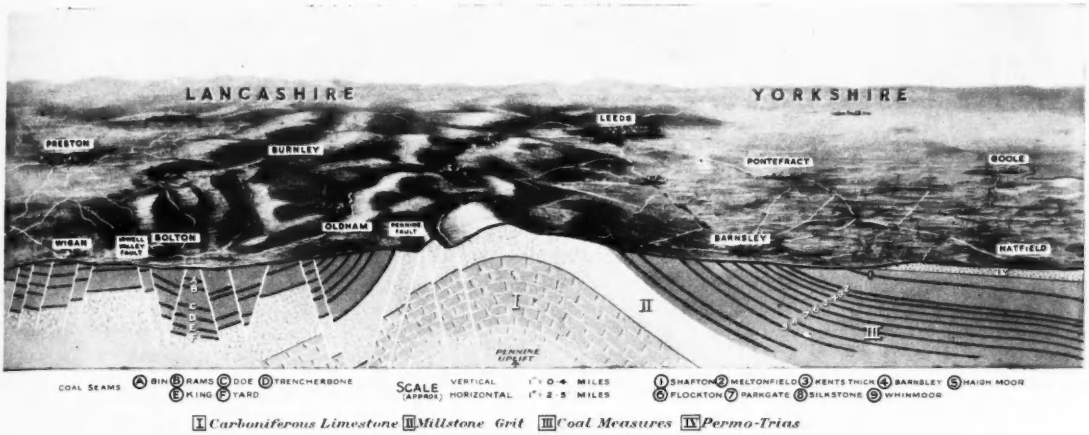


FIG. 9. A diagrammatic section through the Carboniferous coalfields Lancashire and Yorkshire. (*Crown copyright.*)

Cannel. As in durain, the highly disintegrated organic constituents of cannel coal are mixed with small quantities of finely divided inorganic sediment. Cannel differs from durain, however, in being predominantly composed of minute vitrinite fragments, with little or no admixture of micrinite and fusinite. Spores, together with small resin bodies and fragments of leaf cuticles, are usually present in considerable numbers. These ingredients contain the volatile hydrocarbon compounds which constitute such a high proportion of cannel coal.

Boghead. The boghead coals closely resemble cannel in mode of formation, general appearance, and physical properties, but are characterised by the presence of algal remains, which leads to certain differences in chemical composition. All gradations are possible, however, between cannel and boghead coals, the gradually increasing proportion of algal remains being accompanied by a substantial enrichment in hydrocarbon compounds. The variety of boghead coal known as "Torbanite" is largely composed of minute algal bodies, and yields more than 90% of volatile matter on distillation.

Owing to their high volatile content, the sapropelic coals are valuable sources of gases and oils.

EARTH MOVEMENTS AND THE FORMATION OF COALFIELDS

Throughout geological history the crust of the earth has been in a state of unstable equilibrium, and has sought to adjust itself by movements of some parts in relation to others. These movements have involved slow vertical depression or uplift of land surfaces and sea floors, the compressional folding of rock strata, and the displacement of small crustal blocks by means of fracture faults and thrusts.

Thus, the sediments which have accumulated and consolidated in slowly subsiding regions of the earth's crust may subsequently become uplifted, folded and faulted to form new land surfaces. These elevated regions may then be dissected and partly worn down by processes of erosion, before subsidence and submergence initiate another cycle of sedimentation.

We have seen how slow regional subsidences of the earth's crust have been important in the accumulation of coal-forming deposits. Under the influence of later earth movements, originally horizontal coal-bearing strata may be arched into folds and depressions, and dislocated by faults. As a result of prolonged erosion these coal-bearing strata may be stripped off the upfolded regions, but often remain within the relatively protected depressions to form discrete coalfields.

Fig. 9 illustrates the effects of earth movements on the Carboniferous rocks of the Pennine district. The horizontal and laterally continuous "Coal Measures", which once covered most of the region, have been folded, faulted and eroded to form the two coalfields of Lancashire and Yorkshire, separated by the older rocks composing the Pennine "uplift". On the Lancashire side of this uplift the broad depression, or syncline, of Coal Measures strata is crossed by numerous faults, some of which vertically displace the coal seams several thousand feet. In striking contrast with the complexity of the Lancashire coalfield, the structure of the Yorkshire coalfield is comparatively simple, and consists essentially of a wide, shallow basin, the eastern part of which lies concealed beneath a considerable thickness of younger rocks.

THE LIGNITE-ANTHRACITE COAL SERIES

It has been shown that the great diversity of form and chemical composition amongst the coal "types" is due to essential differences in the plant material from which they have evolved. The alteration or metamorphism of peat and sapropel, by geological and chemical processes acting together over long periods of time, results in coals which can be arranged in series with progressive change in properties and appearance. The coals which comprise the lignite-anthracite series have been classified on the basis of distinctive properties into four well-defined "groups", but the placing of boundaries

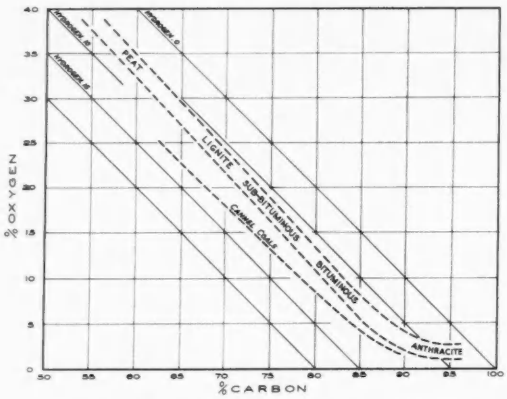


FIG. 10. A graphical representation of the principal changes in chemical composition which occur during the transformation of lignite to coals of higher rank. (*After Raistrick and Marshall.*)

between the groups is purely arbitrary. The transformation of peat to coal in its most highly evolved state can be traced through the series, from the brown coals and lignites—still showing a peat-like character—through the groups of sub-bituminous and bituminous coals—in which clarain and durain figure so prominently—to coals of the anthracite group, where few traces of a plant origin remain apparent. The "rank" of a particular coal depends on the position it occupies in the series, and indicates the degree of alteration which it has undergone.

THE COAL GROUPS

Brown coals and *lignites* represent an early stage in the coalification of peat, marked by a slight increase in the proportion of carbon and a loss of oxygen. Their water content is high, although it may be reduced to only 10% in air-dried samples; the process of drying causes slight shrinkage and cracking of the coal. Lignite is typically more consolidated than brown coal, but both are brown to black in colour, completely devoid of any lustre, and frequently show irregular fracture surfaces. "Jet" is a particularly hard, compact variety of lignite sometimes employed for jewellery and other ornamental purposes. These low-ranking coals contain appreciable quantities of volatiles, yielding between 40% and 55% of hydrocarbon compounds at 900°C.

Sub-bituminous coals are intermediate between lignites and bituminous coals in their appearance and properties.

Bituminous coals are perhaps the most widely distributed and best known of the solid fuels. House-coal, and gas-coal are included in this group, and were originally designated "bituminous" on account of their tendency to burn with a smoky flame and melt when heated in the absence of air. The wide range of properties shown by bituminous coals reflects the progressive enrichment of carbon and the gradual impoverishment in volatiles which accompanies advancing rank.

The low-ranking bituminous coals, having volatile contents ranging between 30% and 45% are the most suitable for the production of coal-gas and producer-gas. High-ranking varieties, containing only 20% to 30% volatiles, generally provide a high-grade coke of the quality required for metallurgical purposes. A low percentage of ash is considered advantageous in domestic and industrial coals, consequently clarain-rich varieties, containing little mineral matter, are the most satisfactory general-purpose fuels.

Anthracites are the highest ranking coals to be produced by the physico-chemical alteration of peat. The transition from bituminous coal to anthracite is not marked by sudden changes in any particular property. Banding gradually becomes less obvious, being virtually absent in higher grade anthracites, and there is a distinct increase in hardness. The regular fracture of most bituminous coals contrasts with the conchoidal fracture of anthracites.

The changes in the physical properties of the higher ranking coals are intimately associated with the continued elimination of volatile constituents, and the consequent enrichment in carbon. High-grade anthracites may contain as much as 95% carbon and less than 5% volatile material. The extremely high ratio of carbon to volatiles in anthracites is responsible for their slow, almost flameless combustion, and poor coking qualities.

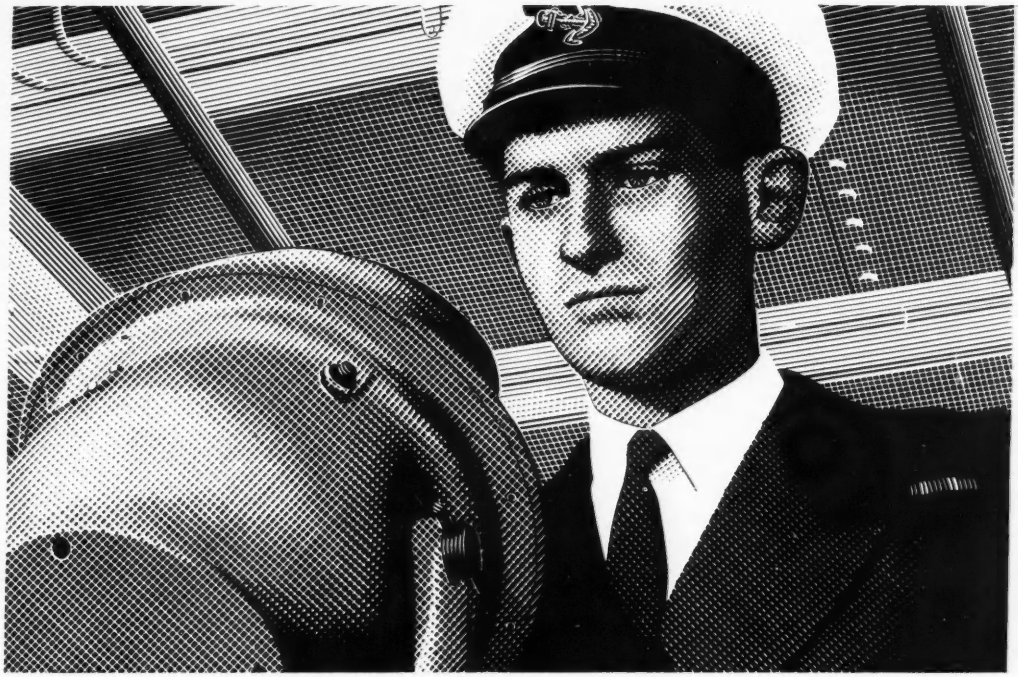
The principal changes in chemical composition which take place during the metamorphism of peat to coals of high rank are graphically summarised in Fig. 10. It can be seen that changes in rank between lignite, sub-bituminous and bituminous coals involve only slight reduction in the total content of hydrogen. It has been suggested that the de-volatilisation which accompanies rising rank amounts to a removal of oxygen, hydrogen and carbon in the form of carbon dioxide and water, in the proportions of $2CO_2 : H_2O$. During anthracitisation hydrogen is eliminated more rapidly than oxygen, and combines with carbon to form methane. The expulsion of methane and water in the proportions $3CH_4 : H_2O$ would satisfy the changes in chemical composition known to occur during the transformation of bituminous coals to anthracites.

Variation in rank has been generally attributed to the effects of pressure and temperature. Where coal seams are covered by thick deposits of later-formed rock, they are subjected to the higher pressures and temperatures normally associated with increasing depth below the surface of the ground (see Fig. 2). It has been discovered that the pressure due to rock cover may rise at a rate of 80 lb. per square inch for each 65-foot increase in depth; the temperature change for the same interval is approximately 1°F, but may vary considerably in some parts of the world.

The conclusion that earth movements are responsible for regional variation in rank is supported by the frequent occurrence of high-ranking coals in regions affected by severe tectonic disturbances.

THE GEOLOGICAL RECORD OF COAL FORMATION

Although conditions suitable for the accumulation and preservation of coal-forming deposits appear to have been widely established during the Carboniferous

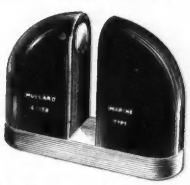


PROGRESS IN ELECTRONICS

Despite its innumerable applications, the magnet is still popularly associated with its use as a navigational aid. This is perhaps not surprising when one considers that the earliest experiments in magnetism were connected with the compass and its use in navigation.

It is said that the Chinese were using a form of lodestone compass in B.C. 2637, but the experimental study of magnetic direction finding devices really began in A.D. 1000 and reached something of a milestone in the 16th century with the work of Dr. Gilbert, who was physician to Queen Elizabeth.

It is only within the last twenty years, however, that revolutionary advances have been made in navigational aids. Radar was, of course, the most important of these advances and it owed its successful development to the invention of an electronic tube known as a magnetron, and this device, in turn, depended for its efficiency upon the "Ticonal" permanent magnet —an alloy having great field strength, stability and uniformity.



Mullard's work in the field of magnetic materials has been particularly outstanding. In addition to "Ticonal" permanent magnets, two other materials now in quantity production are Magnadur, a non-metallic permanent magnet, and Ferroxcube, a non-metallic H.F. core material. These materials are contributing to important developments in other electronic applications such as television receivers and line communications equipment.

Progress in magnetic materials continues, and through this the future may well see developments of equal significance to those which have gone before.

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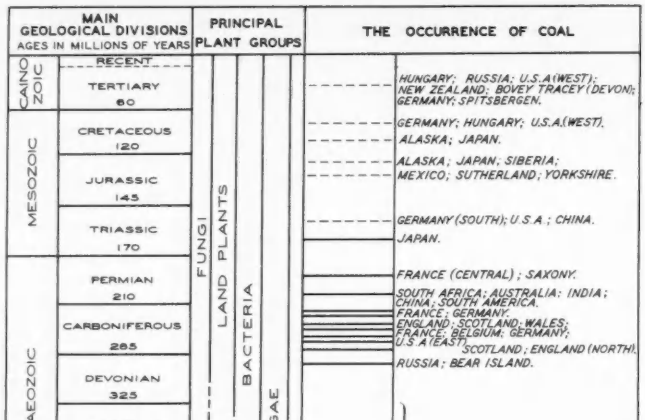

FIG. 11. A SIMPLIFIED TABLE INDICATING THE PRINCIPAL OCCURRENCES OF COAL IN RELATION TO AGE OF FORMATION.
(Crown copyright.)

period, similar conditions have existed at other times in geological history, but over more restricted areas of the earth's surface. Indeed, coal has frequently been formed during the past 300 million years in various parts of the world where favourable conditions have temporarily prevailed. Fig. 11 summarises the geographical distribution of coal deposits, and briefly indicates their relationship in geological time.

The oldest known Palaeozoic coals—of a cannel type—are preserved in rocks of Devonian age on Bear Island near Spitsbergen, and in northern Russia. During the succeeding Carboniferous period widespread coal formation took place in both the northern and southern hemispheres, giving rise to the extensive deposits which now contribute two-thirds of the world's coal supplies. In some regions, notably India, China and Manchuria, Australia and South Africa, the rhythmic cycle of coal formation which began during the Carboniferous period, continued without significant interruption into the Permian.

Most of the Mesozoic coal-bearing deposits occur in small scattered basins, in central Europe, western North America, central Asia and Indo-China, and often equal in richness the deposits of Carboniferous age, though yielding predominantly low-ranking coals. Brown coal and lignites are the characteristic coals of Tertiary age; the principal occurrences are located in central and southern Europe, Russia, western North America, Australia and New Zealand.

The history of coal-formation cannot be said to end with the close of Tertiary times, for younger lignites are known in parts of Canada and southern Russia and the accumulation of plant debris is taking place at the present day wherever conditions allow. In the Everglades of Florida and the Great Dismal Swamp of Virginia and North Carolina, along the Atlantic seaboard of the U.S.A., the remains of swamp trees, reeds and mosses form layers and lenses of peat and sapropel, which are slowly subsiding beneath freshly accumulating material. In other parts of the world similar deposits are now being formed, though nowhere on a scale comparable with that of Carboniferous times. Their transformation to coal will depend on the geological processes which govern the accumulation and distribution of rocks over the earth's surface.

ACKNOWLEDGMENTS

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The author is indebted to the Director of the Fuel Research Station, Greenwich, for providing the photomicrographs illustrated in Figs. 5, 7 and 8, and to the Director of the Safety in Mines Department, Ministry of Fuel and Power, Sheffield, for the photograph from which Fig. 9 has been adapted. Figs. 4 and 10 are reproduced from *The Nature and Origin of Coal and Coal Seams*, by A. Raistrick and C. E. Marshall, with the kind permission of authors and publishers.

READING LIST

The interested reader who wishes to study the various aspects of coal formation in greater detail, is recommended to consult the following books:

Raistrick, A. and Marshall, C. E., *The Nature and Origin of Coal and Coal Seams*, English University Press, London, 1939.

Twenhofel, W. H., *Treatise on Sedimentation*, pp. 351–430, Bailliere, Tindall and Cox, London, 1932.

Stutzer, O. and Noe, A., *Geology of Coal*, Chicago University Press, Chicago, 1940.

Francis, W., *Coal: its Formation and Composition*, E. Arnold, London, 1954.

MICHAEL FARADAY

E. N. PARKER

The standard biography of Michael Faraday is the two-volume Life and Letters of Faraday *by H. Bence Jones. This book, which was published in 1870, is not easily available, and the same is true of several other biographies of this great scientist. For this reason and because of its own qualities, the new book on Faraday by Prof. James Kendall will therefore be welcome. It gives a good insight into his personality, with which this article is concerned.*

There have been two most fortunate conjunctions of personalities in the history of modern science. The first of these was the association of Kepler with Tycho Brahe, whereby the careful planetary observations of the latter—the best and most accurate up to that time—came into the hands of the one man able to make full use of them. The second, some two hundred years later, derives from the appointment by Sir Humphry Davy of Michael Faraday as his assistant at the Royal Institution. Despite certain differences which occasionally marred their personal relations, Faraday felt the same kind of veneration and gratitude towards Davy as Kepler had felt for Tycho Brahe, and there can be no doubt that Davy's quick recognition of Faraday's worth stands high among his own signal contributions to science.

Born in 1791—thirteen years after the birth of Davy—Michael Faraday was the son of a blacksmith who had migrated from Yorkshire to London. The family of father, mother and four children lived in poor circumstances, causing Michael to write subsequently: "My education was of the most ordinary description, consisting of little more than the rudiments of reading, writing and arithmetic at a common day-school. My hours out of school were passed at home and in the streets." At the age of thirteen he became an errand-boy for one George Riebau, a bookseller and bookbinder, whom he satisfied so well that after a year he was accepted without premium as an apprentice to the bookbinding trade—an event that started him on the conscious pursuit of knowledge. For he read the books as he bound them, and what particularly appealed to him were *Conversations on Chemistry* by Mrs. Marcet and the article "Electricity" in the *Encyclopaedia Britannica*. As he wrote later, with the modesty that characterised him throughout life: "Do not suppose that I was a very deep thinker, or was marked as a precocious person. I was a very lively, imaginative person, and could believe in the *Arabian Nights* as easily as in the *Encyclopaedia*; but facts were important to me, and saved me. I could trust a fact, and always cross-examined an assertion. So when I questioned Mrs. Marcet's book by such little experiments as I could find means to perform, and found it true to facts as I could understand them, I felt that I had got hold of an anchor in chemical knowledge, and clung fast to it."

Faraday was encouraged in these studies by his employer, Mr. Riebau, and in the winter evenings of the year 1810–11 he attended a course of lectures on "Natural Philosophy" delivered by a certain Mr. Tatum, the shilling fee for each lecture being provided by his elder brother Robert, who had followed his recently deceased father's calling of a blacksmith. Then, towards the end of his apprenticeship, came the event that determined finally what was to be the lifework of Faraday. A customer at the shop, Mr. Dance, gave him tickets for four of Humphry Davy's lectures at the Royal Institution, and from that time onwards his thoughts were turned exclusively to the idea of a career in science. He wrote to Sir Joseph Banks, then President of the Royal Society, but received no reply, and remained frustrated until he conceived the happy plan of sending his notes on Davy's lectures to the great man himself, and asking for employment at the Royal Institution. Davy, whose own first engagement had been the uncongenial one of an apothecary's apprentice, was impressed by this application and granted him an interview. By the most auspicious of chances, Davy's assistant shortly afterwards was dismissed by the Managers of the Royal Institution for quarrelling with and assaulting one of his colleagues, the instrument-maker. Faraday was thereupon appointed to the vacant position, at a salary of twenty-five shillings a week with residence in the building.

This was in March 1813, and the speed with which Faraday justified his engagement is evidenced by the fact that in the following October he was asked to accompany Davy on a long continental tour through France, Italy and Germany. That such a tour should have been possible at a time when France and Britain were at war, and when Napoleon had practically the whole of Europe in his grip, can only suggest to many minds how much more civilised was the 19th than is the 20th century. But the Emperor, whose genuine interest in science—notwithstanding his strangely short-sighted dismissal of proposals made to him by the American inventor, Robert Fulton, for steam-boats and submarines—had been attested by his inclusion of savants in his Egyptian expedition, gave special permits for Davy and his party. That party was to have numbered five—Sir Humphry and his lady, Faraday, a lady's maid and a valet. But at the last moment the valet declined to go, and in consequence Faraday, largely through the unpleasant attitude of Lady Davy, found some of his duties more menial than he had anticipated. None the less the tour, which lasted until the spring of 1815, was of immense value to Faraday; for not only was he stimulated by this early opportunity of foreign travel, but he was also able to meet many of the leading European scientists of the day. On his return to England he resumed his duties at the

Faraday's statue at the Royal Institution.
(*Courtesy, the Institution of Electrical Engineers.*)

Royal Institution, with a salary increased to thirty shillings a week.

It is not the purpose of this article to describe in detail the work of Faraday throughout the next fifty years, but rather to afford some impression of his character. That he was possessed of genius in the highest degree is universally recognised; among British men of science he may, indeed, be ranked next to Newton. An incomparable gift of intuition, which caused Kohlrausch to say of him that "he smells the truth", largely compensated for his lack of mathematical equipment, although, as Prof. Kendall remarks in his recently published biography of Faraday,* "he must frequently have spent hours hammering out problems that even mediocre mathematicians could have solved in a flash, and he occasionally butted his head against a brick wall when better knowledge would have warned him that he was attempting the impossible". But it is not without interest or significance that another untutored genius, Thomas Alva Edison, should as a young man have studied Faraday's *Collected Researches* and found himself able to understand the simple explanations given therein, and to repeat the experiments so clearly described. Edison, we may feel sure, could have echoed Faraday's words, "It is comfortable to me to find that experiment need not quail before mathematics, but is quite competent to rival it in discovery", even as Faraday himself might have subscribed to Dr. Johnson's dictum in *The Rambler* of May 5, 1750: "The mathematicians are well acquainted with the difference between pure science, which has to do only with ideas, and the application of its laws to the use of life, in which they are constrained to submit to the imperfections of matter and the influence of accident."

Faraday's retort to Gladstone on one occasion is well known. Gladstone, then Chancellor of the Exchequer, had asked loftily what was the use of a certain electrical device that he had been shown, only to get the instant reply, "Why, sir, one day you may be able to tax it!" For Faraday, who was not usually either sarcastic or irritable, this was a remarkable outburst, born, perhaps, of his impatience at the ignorance of science and its potentialities that he encountered in high places. Giving evidence before the Public Schools Commission in 1862, he said—in words some of which seem equally relevant at this moment—"Men of science, fit to teach, hardly exist today. There is no demand for such men. Life is short. The sciences make up life. They are important to life. The highly educated man fails to understand the simplest things of science, and has no peculiar aptitude for grasping them. I find the grown-up mind coming back to me with the same questions again and again."

Doubtless it was disappointment at the limitations which he met in so many examples of the "grown-up mind" that caused Faraday to take such pleasure in the Christmas lectures "adapted to a Juvenile Auditory" which he inaugurated at the Royal Institution in 1826. He was fond of children, although his ideally happy marriage gave him none of his own, and he could be extremely boyish himself, taking a special delight in visits to the circus. Indeed, it was by a visit to Astley's Circus that he celebrated the success in 1821 of his famous experiment in electrodynamics, with a simple piece of apparatus that was, in effect, the first electric motor.

The simplicity and serenity of Faraday's nature may be seen in his religion no less than in the unassuming way in which he treated worldly fame and success. Unlike many scientists and other thinkers of his time, he was never troubled by theological doubts, or at pains to reconcile the creed of his youth with his more mature outlook. To him "that which is religious and that which is philosophical have ever been two distinct things", he wrote to his friend Lady Lovelace; and he remained throughout his life a practising member of the very small and obscure sect, known as Sandemanians, into which he had been born. For a time he was an elder of his congregation, with the duty laid on him of preaching on every alternate Sunday. But when one Sunday he was absent from church because he had been commanded to dine with the Queen at Windsor, he was not only deprived of his office, but was even cut off from ordinary membership. One is reminded of the excommunication of Spinoza by his synagogue in Amsterdam two centuries earlier—except that Faraday was not charged with heresy, and in fact he continued to attend meetings, later becoming an elder once again. A creed which to some must have seemed both primitive

* *Michael Faraday*, by Prof. James Kendall, London, Faber & Faber, 1955, 196 pp., 12*s.* 6*d.*

and narrow was wide enough, in both its faith and its observances, for Faraday.

All the honours that came to him—and by the end of his life they were very numerous—were unsought. He was elected a Fellow of the Royal Society in 1824—unfortunately not without opposition from Davy, who had somehow come to believe that Faraday's work on "the rotatory magnetic motion" had been merely copied from Wollaston's unsuccessful experiments. In money he took no interest whatever; not until 1853 did his salary from the Royal Institution rise as high as £300 per annum, though for the twenty years 1829–49 he received also £200 a year from the Military Academy, Woolwich, as lecturer in chemistry there. From 1836 to 1865 he was, in addition, scientific adviser to Trinity House, which was responsible for the administration and upkeep of English lighthouses. For this he would accept only £200 a year, saying that it was all he required, provided that such a sum should not be regarded as indicative of the importance of the position. It was, of course, typical of him that he should take particular pride and pleasure in this work, which gave him opportunity "to see how beautifully and how wonderfully shines forth among nations at large the desire to do good".

In 1835, largely through the insistence and good offices of friends, Sir Robert Peel, then Prime Minister, was persuaded to recommend that Faraday be granted a pension of £300 a year from the Civil List. Peel, who had won a Double First—in classics and mathematics—at Oxford, could appreciate the work of scientists, but unfortunately at this moment he fell from power and was succeeded by Lord Melbourne. Faraday was with some difficulty induced to see Melbourne, who infuriated him by describing as humbug the bestowing of pensions upon "literary and scientific persons". Some personal scruples Faraday already had on the subject, and after the interview he wrote to Melbourne, saying, "I could not with satisfaction to myself accept at your Lordship's hands that which, though it has the form of approbation, is of the character which your Lordship so pithily applied to it." There was quite a fracas in the Press, *The Times* declaring that "Lord Melbourne grossly insults the first chemist of his day", and William IV came to hear of it. He insisted that Faraday be awarded the pension, not from the Whig Government, but from the King, and after receiving an apology from Melbourne for his "blunt and inconsiderate manner", Faraday accepted it.

Like Newton before him, Faraday suffered a nervous breakdown in middle life, and for several months in 1847–8 he had to take a complete rest. He recovered, however, although he often complained of dizziness and failing memory, and it was not until 1865 that, at the age of 74, he had to give up all work. It is pleasing to know that, in spite of his protests, the Corporation of Trinity House insisted on continuing his salary of £200 a year for life. Seven years earlier Queen Victoria, on the suggestion of the Prince Consort, had granted him the use of a "grace-and-favour" house on Hampton Court Green, and there Faraday died on August 25, 1867, recognised by all his contemporaries, both at home and abroad, as the greatest scientist, and in many respects one of the greatest men, of the day.

PRINTED ELECTRICAL CIRCUITS

C. L. BOLTZ

That the printed-circuit technique is at last available in Britain to any manufacturer of electrical or electronic apparatus is both a tribute to the enthusiasm and conviction of a few pioneers and a disturbing reminder that in this country sloth is still a deadly sin. British Patent No. 639,178 was granted in February 1943, and from then onwards hundreds of manufacturers as well as more immediately concerned military personnel of many Allied nations saw demonstrations of this remarkable technique. Yet the Ministry of Supply rejected the invention and not a single firm could be persuaded to give it a trial. Then in 1947 the American authorities released from secrecy the news that printed circuits had in fact been used at the very end of the war in radio-proximity fuses for anti-aircraft shells. After this the British official attitude changed. The new technique was taken up for guided missiles, walkie-talkies, radar and other devices incorporating electrical circuits. Private manufacturers, too, are realising its importance.

The two men behind a great deal of it—and nothing, of course, can be said about other research on printed circuits that is being done quietly by a number of British firms who do not seem to be publishing their findings—are Dr. Paul Eisler, a refugee Austrian engineer, now a naturalised British subject, and Mr. Harold Strong, who is head of an old-established printing firm. They met in 1941, when Mr. Strong's printing works had just been blitzed, and Dr. Eisler was no longer actively at work because his research on cinema equipment had stopped early in the war. Out of their meeting came Technograph Ltd., which today holds hundreds of patents on printed circuits. Not long ago Pye acquired an interest in this company.

The general principle of the technique can be stated very simply. It is that the hundreds of wire connexions used in even fairly simple apparatus can be produced as lengths of copper foil on an insulating panel by means of known printing techniques. It is important to realise that though the word "circuit" is used in the literature, what is produced by printing is not the

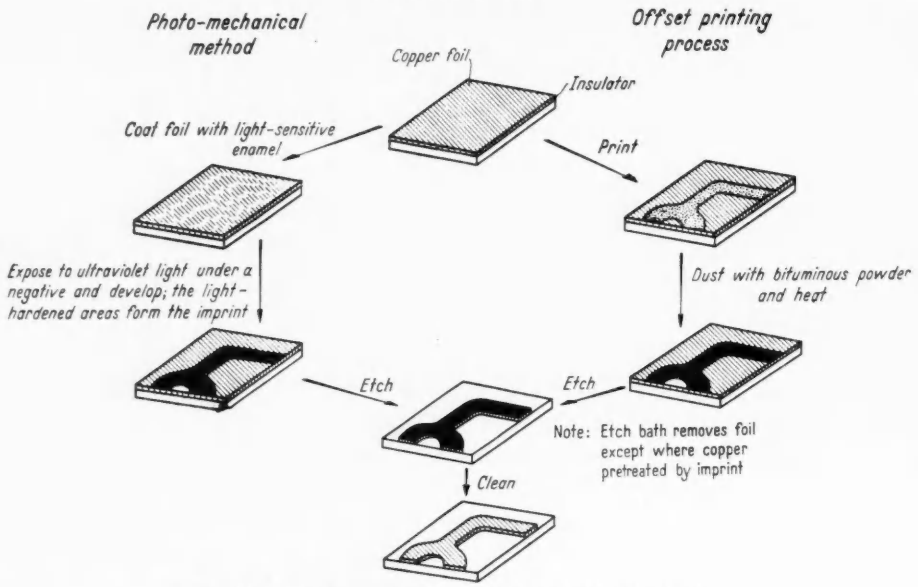
Photo-mechanical method
Offset printing process
Copper foil
Insulator
Coat foil with light-sensitive enamel
Print
Expose to ultraviolet light under a negative and develop; the light-hardened areas form the imprint
Dust with bituminous powder and heat
Etch
Etch
Note: Etch bath removes foil except where copper pretreated by imprint
Clean

FIG. 1. How a "Technograph" printed circuit is made. (*Reprinted from* Research, *November 1954, by permission of the Editor.*)

schematic and geometrically elegant circuit as used in theoretical discussions, but the wiring diagram followed normally by hundreds of workers in the assembly shop.

The printing stock is an insulating sheet on which metal foil is bonded. The material most used so far is a phenol-formaldehyde laminate with a top layer of copper foil about a thousandth of an inch thick bonded in during the process of lamination. There are possibilities for foil made of metal with a low melting point, so that parts can be removed by heat. There is scope for the trial of different synthetic materials, and there is a future for flexible stock such as thin plastic sheet or impregnated paper.

Before printing starts the wiring diagram has to be designed. The usual wiring of apparatus such as, say, a radio receiver, is in three dimensions underneath a metal cover ("chassis"). The wiring diagram has therefore to be redesigned in two dimensions. This is not difficult with a fairly simple circuit where there are few cross-over connexions and no connexions on the vertical sides of the chassis, but even with these complications a two-dimensional design can be made in such a way that the stock can be bent or folded after printing in order to produce a three-dimensional result. And though it is easier for exposition to talk as if the foil layer were on only one face of the insulating board, this is not a necessary restriction. It can be on both faces, giving scope for wiring above and below.

Once the design has been suitably drawn—a possible new specialisation is that of printed-circuit designing—the printing can be done in several ways. The common line-block technique is one. The foil is coated with a light-sensitive film and exposed to ultraviolet light under a negative made photographically from the design. Development then brings out the design on the metal; fixing removes the unused film, leaving unprotected metal. This is then removed by a chemical solvent, which will not affect the design still protected by photographic emulsion, or by electrolysis. The result is a design of metal foil, representing the original design drawing, on an insulating base. A second method is an offset process, which is, it seems, the one preferred by Dr. Eisler. In this the design is printed, from a master, in ink on the metal foil, and is dusted with bituminous paint and heated. This makes an acid-resisting film on the printed part and at the same time fills in minute holes in the ink. After this, as with the photomechanical process, the unprinted foil is removed either by using a solvent or by electrolysis.

With both techniques—and there are others familiar to printers that have been used—the final stage is the removal of photographic emulsion or ink with a suitable solvent.

There is left a sheet of insulating material with the "wiring" in position. The components, chiefly resistors and capacitors, that are normally underneath the chassis are soldered in position in one operation of dipping. The final components that go on top—valves, transformers and the like—are plugged into position and the whole apparatus is almost complete. It is not too fantastic to foresee in the distant future a continuous process of manufacture of such things as simple radio receivers, with a flexible stock going in at one end, being printed and etched and folded, having its components soldered in, and finally being cut into separate receivers by a guillotine.

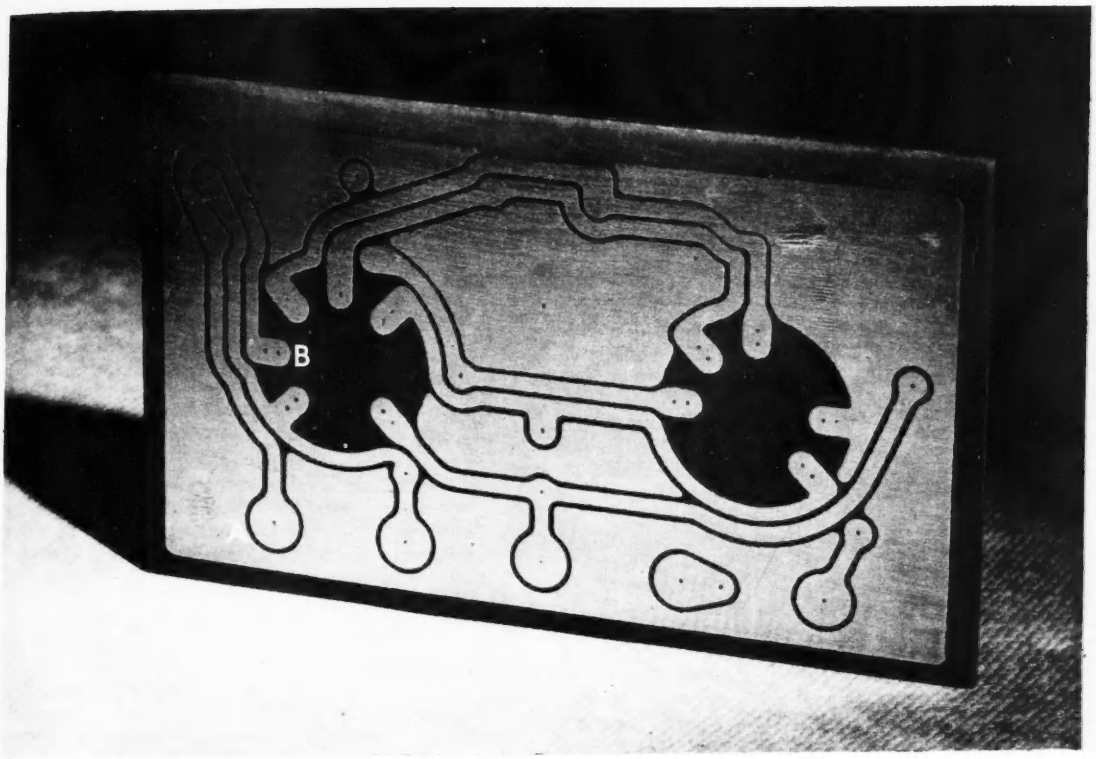

FIG. 2. A simple 2-valve printed circuit. The connexion between A and B as redesigned in two dimensions for printing is easily seen.

The obvious advantages of the printed-circuit technique are in the saving of space (leading to further progress in miniaturisation) and time and labour. But there is more in it than that. There is a predictable and reliable standard of performance owing to the stereotyped procedure and the uniformity of the foil. It is also easy to calculate that for foil free one side, if the width of conducting strip is more than about twelve times the thickness (and it always is in practice), then the surface area is greater than for circular wire of the same cross-sectional area. This means a greater dissipation of heat so that a bigger current can be safely passed. For special purposes the foil can be bonded through very thin insulator to a good heat conductor, in which case enormous currents can be carried by relatively small strips. As much as 400 watts per square inch have been dissipated on test without any detectable damage to the foil.

So far we have been concerned only with the "wiring" of an apparatus, and the first extensive use of printed circuits is likely to be for this only. But the technique can be used for actual components. There are, for example, sensitive strain gauges of spirals or folds of foil on a plastic base. Strain in a surface to which the gauge is bound will cause a change in the resistance of the long length of foil. The high heat dissipation of certain arrangements of foil is especially useful for such gauges.

Resistors can be incorporated in a printed circuit by means of a multiple-layer stock in which one layer is a resistive material such as carbon particles bound in resin. Semi-conductive material could, it is thought, be used instead, bringing the possibility of incorporating transistors in a printed circuit. Transformer windings can be printed and afterwards soldered together. A coil aerial for a portable radio receiver is a simple matter by the printed-circuit method. Even switch assemblies for automatic telephone exchanges can be printed.

Most of these are possibilities of the future and do not at present exist commercially in Britain, whereas in America it is a totally different story. It remains to be seen whether our manufacturers here will now take up the novel printed-circuit techniques, or wait to see what happens elsewhere.

REFERENCE

A substantial set of references are included in the paper "Printed Circuits" by Paul Eisler, which was published in the *Journal of British Institution of Radio Engineers*, 1953, vol. 13, No. 11.

THE EFFECTIVENESS OF COMMITTEES

PROF. JOHN COHEN
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The organisation of scientific work has become increasingly complex, and as a consequence it has involved the establishing of more and more committees. The efficiency of committees thus becomes a matter of scientific importance, and one worthy of scientific study.

If all committees active in the world of science were to be dissolved, much scientific work might be seriously hampered. There are committees in Government Departments and Research Councils, in the Scientific Societies, in Universities and in Research Institutes; and they are often concerned with the tactical conduct of research as well as with strategically planning and directing it and deciding who should do what, when and where. Increase in size and complexity of contemporary problems has taken some of the control of science from individuals to groups. Science is in this respect no different from politics, public administration, industry, or military organisations. We may therefore ask whether such a change is conducive to greater effectiveness. And in particular, is it justifiable to say, as Schrödinger has said in *Science and Humanism*, "Who would expect originality from a committee or commission or board or that sort of thing?" Are the enormous number of hours spent at the committee table, frequently by men of the highest calibre, necessarily devoid of inventiveness? It is worth noting that a generation ago Graham Wallas (in his book *The Great Society*) attacked the procedures employed by Royal Commissions, and suggested that they should develop methods "as unlike as possible to the stereotyped system of question and answer by which most of the Royal Commissions of today save themselves the trouble of thinking about methods at all". Comparable remarks may perhaps be made about our committee procedures.

CRITERIA OF EFFECTIVENESS

The success of committees is often judged in terms of internal criteria; if the committee members feel happy then the meeting is considered to have been effective. As an American investigator puts it "the participants are the best experts on success". It seems to me that this criterion is inadequate because it does not require that the committee should have any link with events outside itself.

An external criterion presupposes that committees are not self-contained closed systems, but exist so as to bring some change into the wider world from which they are drawn. The effectiveness of a committee of management and workers, for example, should be tested not by the amount of mutual conviviality and back-slapping but by the extent of improvement in subsequent industrial relationships. Such an external criterion may be thought of as analogous to a "negative feedback". As such, however, it merely maintains an equilibrium. If we seek innovatory ideas from committees we shall need some psychological device analogous to a limited "positive feedback", which, Dr. Grey Walter has suggested in another context, is the system needed for "exploration and enterprise".*

EXPERIMENTAL STUDIES

The effectiveness of small groups as compared with individuals began to be studied some forty years ago, and in the last decade these inquiries have markedly increased, especially in the United States. Earlier investigators were chiefly interested in the question whether groups are more successful than individuals in solving a given set of problems. Their studies have suggested several points of interest: (*i*) that group discussion yields greater accuracy of judgment as compared with that of individuals; (*ii*) in group discussion there is a tendency to avoid extreme judgments and to converge towards a common opinion; (*iii*) smaller groups are better when the material lends itself to an immediate formation of opinion, and larger ones are better when it is necessary quickly to identify and reject unsuitable proposals or solutions; (*iv*) the superiority of groups over individuals is more marked when the task requires the summation of many different points of view; (*v*) the amount of consensus of opinion in group discussion declines as the group increases in size from five to twelve members, and so does the influence of the chairman (or leader) and the frequency with which members participate.

An experimental approach to the study of committees is not, however, the sole or necessarily the best approach. By itself it is perhaps unlikely to uncover the subtler influences at work. For this purpose a "clinical" approach is needed in which the instruments are not so much sophisticated techniques of experimental design as insight into social processes and some appreciation of the complexity of the human personality, especially in the realm of unconscious motivation. I need scarcely add that the psychological aspect of committees is only one of many that may be investigated.

DISTINCTIVE FEATURES OF SCIENTIFIC GROUPS

We may perhaps be helped to find how new ideas arise in scientific groups by asking what it is that distinguishes the scientific world from the political, administrative, industrial, judicial, military or religious worlds. Let us assume that the scientific world is in fact the most effective in its "social thinking" and has the highest capacity for innovation.

*Walter, W. Grey, "Features in the electro-physiology of mental mechanisms" (pp. 67–78), in *Perspectives in Neuropsychiatry* (edited by Dr. Richter, and published by H. K. Lewis, 1950).

The late Geoffrey Pyke pointed out several distinguishing features. First, there is a tendency among scientists to publish newly-won knowledge as soon as possible and as widely as possible. This practice scatters a large and diverse number of "signals" to fellow workers. Second, scientific issues are continuously discussed in large numbers of formal and informal groups, professional societies and specialist journals. The scientist is thus exposed to a flood of novel ideas. Third, discussion is absolutely free; anyone can talk to anyone, and what matters is not who you are but what you say. Fourth, the scientist is always seeking examples of situations where the usually accepted way of doing things is a hindrance. He challenges practices or assumptions whatever their age, history or prestige, and however much sanctified by tradition. When he thinks he discovers a shortcoming in someone else's work he makes it a common experience, just as a medical officer reports to his fellow physicians a suspected case of infection. All concerned can thus be on their guard, and even if they are unwilling to accept the data or the interpretation or the inferences, their minds will have been prepared for receiving further observations of this kind. The alternative to such a procedure is that nothing will be changed until there is something like a crisis.

New ideas do not only come when we meditate in isolation. A fresh idea may occur to us during conversation, and it may ignite a train of thought in us in a fashion imperceptible at the time but fully appreciated later. For such effects to take place it is essential to be able to *listen*, which means coming as close as possible to the other speaker's understanding of what he himself means.

When a group of scientists sit in committee they are not therefore in an artificial situation. The capacity to integrate our perspectives with those of different individuals as well as the different aspects of our own personal experience is a vital element in the development of our powers of thought. A reciprocity of perspectives then becomes possible. We are reminded of the Socratic view as expressed by Cassirer: "Truth . . . cannot be gained except through a constant co-operation of the subjects in mutual interrogation and reply. It is not therefore like an empirical object; it must be understood as the outgrowth of a social act." Truth is not "a ready-made thing" which can be "grasped by an effort of the individual thinker and readily transferred and communicated to others".

Indeed the whole history of thought, as Dr. Agnes Arber has recently remarked, is permeated by the method of discourse or disputation, a method which enables us to bring out fine nuances and point to a possible reconcilement. The Platonic dialogues, Dr. Arber suggests, have such a structure which represents "a transition to the full dramatic mode—that mode in which Shakespeare formulated the innumerable aspects of his own vision". It is the most effective way for expressing incompatibilities and harmonies alike. The dramatic form—"gives opportunity for a number of sequences instead of one . . . It serves to reveal the multifarious facets of reality".

OBSTACLES TO COMMUNICATION

I have referred to the importance of absolute freedom of communication. Indeed I would assume that optimal conditions for group effectiveness are approached only when freedom of utterance is not less than freedom of private thinking. If one is less free to say to others than one is to speak to oneself, the possible advantages of the presence of others are unlikely to be reaped.

Let us therefore consider some of the factors which may adversely affect group communication. First, we should perhaps mention the effect of professional homogeneity of the members. When a committee consists of members who are professionally much alike, the mutual understanding they are likely to reach may be rather limited. Unimportant minutiae tend to create emotionally toned disputes; relatively trifling matters may assume disproportionate significance and high feeling spread to larger issues. The degree of feeling invested in a point at issue between two or more persons may be a function of the closeness of their viewpoint. Homogeneous groups may therefore be more unstable than heterogeneous groups and less likely to agree on broad issues—one Lord President of the Council is said to have described one of his homogeneous advisory committees as "a bear-garden".

Another factor is the tacit assumption of members that agreement is desirable as an end in itself. This assumption tends to lead the group away from the exploration of differences, which is perhaps their primary task. There is a shrinking of the field to exclude whatever provokes anxiety, a tendency to conform to the group and to yield to its pressures, in short, a *compulsion to agree*. A free expression of view is difficult in such circumstances. The nearer a group moves towards a decision, the more a divergence will threaten its solidarity. The compulsion to agree therefore seems to grow stronger as the time for decision approaches. Not that stormy meetings are unknown, but, generally speaking, differences are kept strictly under control. Even when an attempt is made to express a divergent point of view the effort is usually abandoned in the end. One or other party, often the less voluble or less dominant, surrenders. The differences are limited. The compulsion to *disagree* also occurs, but it seems to be much more rare.

Some experiments which offer some support for this notion of a compulsion to agree have been carried out by S. E. Asch. In the experiment one member of the group is placed by the experimenter in a relation of conflict with the rest of the group by making the other members his accomplices. The effect of this on the individual's judgment is then determined. For example, the members of the group are asked to match a given line with one of three unequal lines, one of which seems to the ordinary person obviously similar in length to the given line. The one "naïve" member who gives this judgment finds himself contradicted by the others, who act in complicity with the experimenter and have been instructed beforehand to give false judgments. Each member of the group announces his

judgment publicly. The effect of the majority in compelling agreement on the part of the individual in the minority may be measured by the frequency of errors made by "naïve" members in the direction of the distorted estimates of the majority.

From these studies it seems that, in a number of experiments, about one-third of the minorities of one found themselves agreeing with the majority. The effect was more marked as the basis for initial judgment was less definite. The individuals in the minority admitted afterwards that they felt disoriented, doubt-ridden, with a strong desire not to appear different from the others.

Many variations of this experiment are possible. For instance, in order to determine the effect of a non-unanimous majority, one of the accomplices is asked to deviate in certain specified ways. The majority effect is then found to be much weaker. A unanimous majority of three seems more compelling than a majority of eight and one dissenter. The compulsion to agree seems to diminish when there is some support for divergence.

I have elsewhere suggested that some of these difficulties might be overcome by using the technique of role-reversal, whereby members accept the rule that no one is allowed to disagree unless he can convince the rest that he fully understands the view from which he is dissenting.

I previously made use of analogies with different kinds of feedback. Such analogies should not be pressed. Communication between persons has characteristics which do not arise in electrical engineering. The proverbial visitor from Mars would make little of our social relationships if he merely studied our postal and telephone services without opening letters and tapping messages. Apart from the channels of communication, there is also the content of the message to be considered. A person may send an ambivalent message intending one meaning consciously and another unconsciously. The receiver may likewise receive the message ambivalently. One and the same message—for example, a remark addressed to several people at a meeting—may be received with different meanings by the several listeners. The manifest content of a message is not the same as its latent content. In irony, for instance, instead of saying what one thinks one pretends to think what one says. Similarly, a conventionally expressed statement conveys very little; the more conventionally a statement is made the less confidence we should have in our interpretation of it.

Many physiologists have sharply criticised the analogy of nervous action with a telephone system. The criticism has even more point if the analogy is extended to social contexts, because a message received by the listener is not necessarily the "same" as the sender *thinks* he has sent or that the listener *thinks* he has received.

Communication may also be affected by so-called "parataxic" distortion. When this happens we attribute imaginary characteristics to another member of the group. We see him not as he is, but as endowed with qualities which we have previously associated with a different person, particularly a person who has evoked in us profound feelings of affection or hostility.

Another point to note is that people may communicate to one another vocally, not merely verbally. In vocal communication, the intonation, emphasis, rate of speech and ease of expression may effect the content of the message. It is even possible to communicate non-vocally. Silence is not a neutral background for the spoken word. Without silence speech would be meaningless. We understand what is said by what we leave unsaid or by when and for how long we leave it unsaid. A person's silence may have one or more of several possible meanings. By the same silence he may wish to convey different meanings to different people present. Or he may wish to conceal the true meaning of his silence and camouflage it later when he decides to speak. A long period of silence may be a sign of compliance or an ominous sign. To withhold speech often means an aggressive intention. The reticent member of a committee may be turning over in his mind whether he should resign. Perhaps he does not trust himself to speak. An instructive analogy may be drawn between the silent committee member and the silence of the "unwilling" psychiatric patient. Both may be lost in phantasy which has a paranoid content or are so repressed that they may not be able to think of anything to say. And just as the proper timing of the restatement of a patient's problem is crucial so the committee chairman's timing in restating the group's problems may be decisive for similar reasons.

In conclusion I venture to suggest that we should not hastily dismiss the possibility of truly productive thinking in committees. A person's thoughts are perhaps always bound up with "invisible" groups. They are not spontaneously generated. They have a social and personal history. The effectiveness of a committee, as judged by external criteria, will be fully manifested when its members are more or less free from inhibition and when they are optimally receptive to one another's ideas. It is true that a new idea must arise in the mind of some individual, but when he participates in a group he can assimilate the thoughts of others and accommodate to them in a way which is impossible when he is alone. Only when we understand how a committee (or other group) works can we fully utilise its intellectual potentialities.

SHORT READING LIST

Further papers on the subject by the writer:

"The Technique of Role Reversal", *Occupational Psychology*, 1951, vol. 25, 64–6.

"Some Working Hypotheses and Provisional Conclusions in the Study of Committees and Conferences", *Occupational Psychology*, 1952, vol. 26, 70–7.

"Social Thinking", *Acta Psychologica*, 1953, vol. 9, 146–58.

"Individuality of Thought", *Bulletin of the John Rylands Library*, 1954, vol. 37, 103–19.

(With C. E. M. Hansel and E. May.) "Natural History of Learned and Scientific Societies", *Nature*, 1954, vol. 173, 328–33.

A review of some recent studies will be found in *Handbook of Social Psychology*, 1954, vol. 2, edited by G. Lindzey.

The following is also of much interest: "The Technique of International Conferences", *International Social Science Bulletin*, 1953, vol. 5.

The world-famous museum of science and technology at Munich. The exhibition with its clock tower is seen on the right. Next to it is the library, and on the left is the congress building.

MUNICH'S "DEUTSCHES MUSEUM"

EGON LARSEN

A twenty-five-year-old engineer from Munich was among the visitors to the Electrotechnical Exhibition in Paris in 1881. His name was Oscar von Miller, and he was the son of Bavaria's famous brass-founder, Ferdinand von Miller. He marvelled at Edison's incandescent lamp, and listened to a transmission from the Opera House by telephone. His enthusiasm for the new wonders of the technical age was as strong as his admiration for the pioneers of science, and so he paid many visits to the *Conservatoire des Arts et Métiers*, spending hours in front of Lavoisier's laboratory, the remnants of one of Montgolfier's balloons, and Jacquard's first loom. A year or two later, he went to London, mainly to see the Science Museum at South Kensington; what impressed him there most of all was the kind of people who went to see it: the youngsters, and whole working-class families.

An idea had taken root in his mind—Munich ought to have a similar museum of science and technology, and he would make it his ambition to create one. But it took him over twenty years to get as far as the starting-point; in the meantime he had made a name for himself as one of Germany's most gifted hydro-electrical engineers and power transmission specialists. So when he submitted his plan at the general meeting of the *Verein deutscher Ingenieure* in 1903 it was greeted as the ambitious but feasible idea of a man who knew what he wanted.

Oscar von Miller's impressive personality carried him through to success where other men might have failed. His rhetorical temperament was as irresistible as his charm, which he used extensively for wheedling help, gifts, or money out of people and authorities. The town of Munich put an island in the river Isar at his disposal, industrial firms promised original machines and models, wealthy citizens gave money, the Bavarian Crown Prince (later King Ludwig III) became the patron of the whole venture, and when the Kaiser laid the foundation stone in 1906 von Miller talked him into giving £5000 for a large section model of a battleship.

The museum's reconstruction of an alchemist's laboratory.

Although personally a man of very modest habits he would use any trick to further his aims. Once he made his workmen fix cardboard sheets of an especially ugly colour over the door-frames as he was expecting the visit of some gentlemen from the quarry industry; by this device he extracted from them a substantial gift of marble for the door-frames of the Museum halls! Von Miller's genius for getting what he wanted became so proverbial that it gave rise to the following somewhat apocryphal anecdote: von Miller was travelling through Mexico during a visit to the New World, when the train was suddenly attacked by a gang of robbers. They took all the valuables from the passengers, but when the leader saw von Miller's name in his wallet he returned it with the words, "I beg your pardon, señor—it is our principle never to take anything from a colleague."

THE ART OF LEAVING THINGS OUT

The main Museum building was more or less completed when the First World War broke out. Work was interrupted then for a long period and not until 1925, on von Miller's seventieth birthday, was the *Deutsches Museum* opened with a festive procession which brought all Munich out into the streets, and tens of thousands of visitors to the town.

Right from the start, the *Deutsches Museum* was tremendously popular; it became firmly established as a Munich institution no less characteristic of the town than the *Hofbräuhaus* beer-cellar or the English Garden. But its founder enjoyed the success of his work for only eight years; when the Nazis came to power in 1933, he resigned from the post of director because, as he told his intimate friends, he "did not want to betray" those who had helped him, meaning the scores of Jewish scientists and industrialists who had contributed to the collections. A year later, von Miller died; he was spared the experience of seeing his work first mutilated by the elimination of exhibits of "non-Aryan" origin, and then shattered by bombs.

At the outbreak of the war, the precaution was taken of moving a number of irreplaceable exhibits into the cellars; others were stored for greater safety in a monastery and in a castle in northern Bavaria. Until the middle of 1944, the vicinity of the Museum escaped damage by Allied bombers, but then came a series of raids, between July 1944 and January 1945, which destroyed most of the buildings, and damaged or smashed to pieces the exhibits which had been left behind. There is a suspicion among the museum people that Allied agents had reported the occupation of a whole floor of the building by the notorious *Organisation Todt*, which was responsible for the abduction and enslavement of

The planetarium in operation. The stars are projected on the ceiling of a dome above a silhouette of the Munich skyline.

foreign workers; this organisation stored arms and ammunition in the library alongside its stock of 250,000 valuable books. The bombs may have been aimed at the Museum, because it housed this Todt unit. At any rate, when the war ended the Museum was little more than an empty burnt-out shell with 5000 broken windows.

Reconstruction, under the energetic directorship of H. Baessler, has now been largely completed; on May 7, 1955, in honour of Oscar von Miller who was born 100 years ago on that day, the President of the Federal Republic, Theodor Heuss, opens the last halls of the Museum to be rebuilt and re-equipped with old and new exhibits.

This Museum is the perfect example of the extent to which the "art of leaving things out" can be carried. The collections have been arranged according to the principle that confusion must be avoided even if it means severe selection of the exhibits. Every section has its own "centre of gravity", around which are grouped only the most important milestones in the development of the particular branch of science or technology. The designs of the halls and the arrangement of the exhibits are simple, clear, and easy to survey. Another important principle is that wherever feasible the visitor must be able to try out things for himself, work models, and "learn while twiddling the knobs".

THE "PROGRESSEUM"

Accordingly, the visitor can look at the bones of his own hand in the x-ray cabinet, repeat Otto von Guerick's famous vacuum experiments of 1652, smell the various coal products developed by modern chemistry, and test a great number of natural laws by means of cleverly contrived instruments; the 1 million volt generator in the high-tension section, however, may be operated only by an attendant: it produces an artificial stroke of lightning, demonstrating its effects on a house without a lightning-conductor.

There is a particularly instructive piece of "visitor participation" during the twice-weekly demonstrations at the 300-millimetre refracting telescope: a photograph of the moon is taken, developed in the presence of the watching group of visitors, and each of them is then given a print to take home.

The Museum has a great wealth of historical apparatus, such as the original equipment with which Heinrich Hertz produced and observed his electro-magnetic waves (a pathetic little contraption of wood and wire); the famous "singing knitting-needle" with which Philipp Reis demonstrated the first transmission of sounds by electricity to his fourth-form pupils; the first motor vehicles built by Daimler and Benz simultaneously, but without knowing anything of the other's efforts (as a

Preserved in the museum is the original working table used by Professor Otto Hahn while carrying out his classic experiments leading to the discovery of uranium fission.

matter of fact they never met before or after although they lived and worked only a few miles from each other); Siemens-Schuckert's first alternating-current locomotive; Justus von Liebig's and Adolf von Bayer's chemical equipment, most of it surprisingly primitive; Prof. Otto Hahn's work-bench where he made his studies leading to the discovery of uranium fission just before World War II.

There is also the magnificent Zeiss Planetarium where visitors can watch the movements of the stars and planets above a charming silhouette of the roofs and spires of Munich. A beautiful reproduction of a medieval alchemist's "kitchen" contrasts with an enormous representation of the periodic system of the elements in the form of a spiral reaching from the bottom of the hall to its cupola. And there is a special favourite with the young, an automatic trumpeter of 1801, which sounded the opening notes of the festival concert on the occasion of the fiftieth anniversary of the Museum a couple of years ago.

Since its opening in 1925, more than 26 million visitors have seen the Museum, though very few can have walked along the whole of the nine miles of halls and corridors. It is true to say that this is not a technical museum in the conventional sense—it has been called a "Progresseum" because it is keeping pace with the never-ending progress of science and technology. This characteristic is especially marked in the sections to be opened by President Heuss in May: there will be the famous steam hammer, "Fritz", a 1000-hundredweight giant made by Krupps in 1861, which was in operation until 1911 and has now been reconditioned so that it can be demonstrated in the Museum, and a Bessemer converter of 1874. Representing the other end of the time-scale there will be a completely new hall which shows, for example, welding and soldering techniques with the very latest machines. The Museum's historians have also been ferreting out old machines and tools used up and down the country in one-man workshops, and these will be on show for the first time. An original steam-engine by James Watt, which had been shattered by bombs, has now been completely repaired with the help of a Federal Railway expert, who was sent to the Science Museum at South Kensington for three months to study its Watt engines.

Apart from the library with its substantial collection of books and manuscripts the Museum buildings contain a beautiful large hall for concerts and congresses, and the Federal German Patent Office is also housed in the premises. Altogether, the *Deutsches Museum* is a very lively and important institution in present-day Germany, most valuable to the historian as well as to the practical technical and research worker, and a source of never-ending fascination for the youngsters of Munich.

BRITAIN'S ATOMIC PROGRESS

A SUMMARY OF POST-WAR DEVELOPMENTS

In connexion with the Government White Paper on the nuclear power programme, the Atomic Energy Authority prepared a document giving the key dates and outlining the major developments in the history of Britain's post-war effort in the nuclear energy field. The facts it contained have permanent reference value, and we therefore publish a summary of it for the benefit of our readers.

When the war ended the British Government immediately decided to embark on a programme designed to exploit the possibilities of nuclear power. It was necessary first to build up an organisation capable of carrying out the essential research work and for producing the materials which must be available whether for the production of weapons or for the construction of power stations. The key stages by which the position has now been reached that atomic weapons have been produced and atomic power stations can be constructed are as follows:

October 29, 1945. The Prime Minister (Mr. Attlee) announced in the House of Commons that an Atomic Energy Research Establishment was to be set up at Harwell. Responsibility for atomic energy matters would be transferred from the DSIR to the Ministry of Supply.

January 29, 1946. The Prime Minister announced the Government's plans for the production of fissile material. Lord Portal was appointed head of the production organisation; Prof. J. D. Cockcroft (now Sir John Cockcroft) was appointed director of Harwell.

March 28, 1946. The Minister of Supply (Mr. Wilmot) stated that the site for processing raw materials would be at Springfields, Lancashire. (The headquarters of the whole of the Production Group was set up at Risley, Lancashire, under the direction of Sir Christopher Hinton.)

October 10, 1946. The setting-up of a Radiochemical Centre at Amersham for processing, packing and distribution of natural and artificial radioactive substances was announced.

November 6, 1946. The Atomic Energy Bill, giving the Government power to control the use and development of atomic energy, received Royal Assent.

July 23, 1947. The Minister of Supply announced that an establishment (now known as the Windscale Works) for the production of fissile material in a chain-reacting pile was to be built on the site of the Royal Ordnance Factory at Sellafield.

August, 1947. Britain's first atomic pile, known as GLEEP (Graphite Low Energy Experimental Pile), at Harwell was stated to have started operating. Built primarily for experimental work in nuclear physics, it was designed largely by a New Zealand group of scientists, though many British scientists contributed to the production of the pure graphite and uranium, and designed and produced instruments which were required.

September, 1947. The first delivery of British-produced radioactive isotopes to a hospital was made. (Since then production and use of these materials has developed considerably; the present rate is in the region of 20,000 consignments a year, of which more than one-third are exported.)

July 3, 1948. The second British atomic pile—BEPO (British Experimental Pile)—started working at Harwell. This graphite-moderated, air-cooled pile was designed according to basic calculations begun in 1945 by a team of scientists working under Sir John Cockcroft in the Laboratory of the National Research Council of Canada.

March 6, 1949. It was stated that plutonium was being produced at Harwell on a small scale, but sufficient for investigation of the chemical and engineering problems to be met in large-scale handling of plutonium.

June 25, 1949. Completion of the "hot" wing of the radiochemical laboratory at Harwell was announced. Here plutonium was extracted from irradiated uranium.

November 14, 1949. It was announced that a site had been selected at Capenhurst, Cheshire, for the construction of a new atomic establishment. Its purpose was kept secret for a time, but later it was stated to be a gaseous diffusion plant for the enrichment of uranium by separation of the heavier uranium 238 atoms from the rarer uranium 235 atoms.

December 2, 1949. The Harwell cyclotron was given its first full trial, less than three years after work on it had started. It can accelerate atomic particles to a speed of 95,000 miles a second and is a valuable tool for basic atomic research.

December, 1949. It was announced that work on one of three piles planned for the Windscale Works, Sellafield, had been suspended. This was due to a review of the Atomic Energy programme, and work on the other two piles was, as a result, accelerated.

April 1, 1950. The Radiochemical Centre at Amersham, previously operated by Thorium Ltd. as agents for the Ministry of Supply, became an outstation of Harwell. The Ministry of Supply announced that a new atomic energy establishment was to be constructed at Aldermaston, near Reading, Berks. This is now known as the Atomic Weapons Research Establishment, and its director is Sir William Penney.

March, 1951. An Isotope School was established at Harwell to give training in the techniques of handling radioactive isotopes. Up to the end of 1954, 350 students had attended this school from twenty-nine different countries including Britain.

October, 1952. Britain's first test of an atomic weapon took place at the Montebello Islands, Australia.

May, 1953. Construction started on the first atomic power station. This is sited at Calder Hall, Cumberland, near the Windscale Works, and consists of two natural uranium graphite-moderated piles cooled by gas which draws off the heat generated in the piles and transfers it to heat exchangers. Here steam is created to supply the generating plant. No official forecast has been made of

the power output or date of completion, but unofficial estimates are that in 1956 power of the order of 50,000 kilowatts will be supplied to the national grid system.

October, 1953. Two further tests of atomic weapons took place at Emu Field on the mainland of Australia.

January 1, 1954. The Department of Atomic Energy was formed under the Lord President of the Council to take over responsibility for atomic energy until the formation of an Atomic Energy Authority.

February, 1954. It was announced that an experimental reactor of the "breeder" type, known as Zephyr (based on the initials of Zero Energy Pile), had started operating at Harwell.

March, 1954. It was announced that an experimental reactor of a new type capable of producing power was to be built at Dounreay in the north of Scotland. The atomic unit for this will be a fast breeder reactor of the type in which it is expected that more fissile material, such as plutonium, will be created in a surrounding "blanket" of uranium or thorium than is consumed in the core of the pile.

May, 1954. Work was started on the construction of a heavy-water reactor (known as E.443) which will be used for materials testing and production of isotopes.

July, 1954. It was announced that the United Kingdom and New Zealand had agreed to collaborate in a project for a power station (not atomic) and production of heavy water.

August 1, 1954. The Atomic Energy Authority, with Sir Edwin Plowden as chairman, came into being as the organisation responsible in Great Britain for research and development in this field. It controls all atomic establishments. The Lord President is the Minister responsible to the Government for atomic energy matters, and the Ministry of Supply is responsible for supplying weapons to the Services.

September, 1954. The Reactor Training School, to enable industry to increase its participation in the development of atomic power, was opened at Harwell.

SENDING SCIENTIFIC PAPERS BY WIRE

Tele-facsimile is used to transmit photographs in the newspaper industry, and is also used to provide copies of weather charts at a number of different points simultaneously. A tele-facsimile service is now in use in both Oak Ridge Laboratory of the U.S. Atomic Energy Commission and in the U.S. Library of Congress to reproduce scientific papers.

The library system is a development of the method by which photographs are transmitted by wire. A reader-transmitter scans the reading matter to be transmitted with a flying spot of light to read the print in a thin line from left to right. The reflected light from the blacks and whites of the print is picked up by a series of photomultiplier tubes which convert the varying reflections into electrical impulses. The length of the scanning line can be adjusted to suit columns of different width and the copy holder moves automatically to advance the lines to meet the scanning spot. It is claimed that anything from a single sheet of paper to a three-inch volume can be accommodated and that drawings can be transmitted as easily as print.

The impulses from the transmitter are sent over an ordinary telephone cable to a distant recorder which will reproduce a completely legible and permanent black-on-white copy at about 120 square inches a minute. A further feature is that adjustments can be made so that direct enlargement takes place and the copy-as-received can be anything up to a 4 to 1 enlargement of the original. In the receiver an electrolytic process is used in recording and this cuts out conventional photo-developing and printing which involves the use of wet chemicals.

To test the system at Oak Ridge a request was made at one laboratory eight miles from the central library for a two-page article. The journal containing the article was located, the correct reference found, the volume put into the transmitter and a tele-facsimile recording of the required article was in the hands of the person requesting it within 4½ minutes of his asking for it.

Both the sending and receiving units are simple in the extreme to operate—it is claimed that a "non-technical" operator can be trained in less than a day.

There are certain obvious gains in the use of a system of this type. In the case of the Oak Ridge Laboratory, for instance, there is always the uncomfortable possibility that journals, books and so on may become contaminated with radioactive material and it is clearly the safest method for all to be able to offer an expendable copy while the original remains virtually untouched within the confines of the library. In the case of rare documents or those in great demand it is obvious, again, that a method which will provide a copy quickly and clearly—and even an enlarged copy at that—and leaves the original ready for further calls all in a matter of minutes affords an opportunity for greatly increased and enhanced service.

The U.S. Library of Congress has been operating this system experimentally for about six months. The transmitter is in its loan division and the receiver—the only one linked up at the moment—is at the National Institutes for Health at Bethesda, about ten miles away. The set at Oak Ridge has been going for about three years, again with only one receiver.

This most interesting development of a tele-facsimile system is likely, for a long time to come, to be of passing interest only to the librarians of countries outside the U.S.A. The cost of installation is probably not a small one, and to make such a system really worth while it would be necessary to provide a network of transmitters and receivers after the fashion of teleprinting installations.

REFERENCES

Wilson Library Bulletin, January 1952, vol. 26, No. 5.
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THE BOOKSHELF

Radiobiology Symposium 1954

Edited by Z. M. Bacq and P. Alexander. Proceedings of the Symposium held at Liége August–September 1954 (*London, Butterworths Scientific Publications, 1955, 362 pp., 60s.*)

Fundamentals of Radiobiology

By Z. M. Bacq and P. Alexander (*London, Butterworths Scientific Publications, 1955, 389 pp., 40s.*)

Actions of Radiations on Living Cells

By D. E. Lea (*London, Cambridge University Press, 2nd edn., 1955, 416 pp., 30s.*)

The world is entering the Atomic Age, and with every advance made in this field the number of workers who are exposed to radioactivity is increased, which raises a serious problem because of the biological hazards involved. The injurious effect of x-rays on living matter was recognised almost as soon as this kind of radiation was discovered, and efficient protective measures have long been applied. On the other hand much has still to be learned about the high-energy radiation encountered in many establishments nowadays. This is the reason why since the end of the last war research into the basic mechanism of radiation effects has proceeded so intensively, and a measure of the amount of work now being done in this field is provided by the fact that "Radiobiological Conferences" have become annual events. The last such meeting, which was held in Liége in September 1954, attracted about 140 experts from thirteen countries. The first volume under review contains the proceedings of this symposium.

Amongst the many interesting topics raised at the conference, a few may be mentioned to show the advance made in the field of Radiobiology by physicists, chemists, biologists and clinicians.

The possible nature of the chemical reaction by which absorbed energy may be utilised in living matter has been described by A. Chevallier and M. Ebert. According to them, ionising radiation decomposes aerated water into molecular oxygen and hydrogen to form hydrogen peroxide which may be one of the active agents responsible for radiation lesion. Miss T. Alper has shown that the radicals which inactivate bacteriophage can be derived from the decomposition of hydrogen peroxide.

The modification of the radiation effects by chemical agents, particularly by cysteamine and related substances was discussed by H. M. Patt, A. Hollaender and Z. M. Bacq, and it seems that the "protective" action occurs at an early stage in the chain of the secondary events which are set in motion by the primary ionisation. P. Alexander, A. Charlesby and M. Fox on the other hand have shown that the degradation of the irradiated polymer (polystyrene), which is an immediate and direct effect, can be prevented or reduced by amines, thiourea and other substances. The importance of tissue shielding and transplant as modifying factors for radiation injury to specific physiological systems was presented by L. O. Jacobson, L. J. Cole and several other participants. M. Errera gave a very interesting survey on the action of ionising radiations on cell constituents, and drew the conclusion that the only clearly apparent immediate effect of ionising radiation appears to be on the deoxyribose nucleic (DNA) metabolism. The influence of irradiation on DNA synthesis has been studied by L. G. Lajtha and B. E. Holmes, and the important data obtained by them show how radiation may be used as a tool to investigate some of the finer details of cellular metabolism. By employing deuteron bombardment, E. Pollard determined the molecular size and thickness of enzymes and threw more light on the internal structure of viruses and phage.

The effect of radiation on chromosomes and genes was another important subject of the Liége Symposium. The frequencies of chromosome aberrations and gene mutations were used to measure the effect. By this method the relative efficiency of various radiations has been determined and the influence of oxygen on radiation reaction has been more accurately analysed. Comparison was also made between the radiation-induced chromosome aberrations and those induced by chemical agents.

The gist of the discussions which followed the various papers is included in the book, and shows not only the keen interest but also the differences which at present exist amongst the research workers as regards the interpretation of the various radiobiological phenomena.

The Liége conference demonstrated that the problems of radiobiology are very diverse and demand the attention of specialists of many scientific subjects: physics, biochemistry, physiology, cytology, genetics and radiotherapy. *Fundamentals of Radiobiology* will help specialists to see their own contribution in relation to the other aspects of radiation research. The book surveys the present status of research in this vast field, and embodies the review of 960 original papers in its seventeen chapters. The first four chapters deal with the physical and chemical aspects of radiation. The cytological effects of radiation and that of the "radiomimetic" substances are briefly discussed in chapters 5, 6 and 7. The role of oxygen in radiation reaction is described in chapter 8. The differences in radio-sensitivity and the pathological biochemical changes observed after radiation are dealt with in chapters 9 and 10. The next section of the book reviews the problems of protection from radiation injury by various methods, and it includes much original work by the senior author. The last chapter describes the effects of radiation on man and deals with such matters as radiation sickness, the results of the atomic explosions and accidents affecting workers exposed to radioactivity. It also contains a brief but timely reference to the genetical hazards. The selected subjects are clearly presented and well documented. The book will no doubt satisfy a great demand not only by those who are engaged actively in this field, but also by those who are interested in the various problems associated with radiation.

The demand for information about the biological effect of radiation led to the reprinting of Lea's book, first published in 1946. It was a monumental work at the time and has served as a useful guide in post-war research. The author was an ardent exponent of the target theory, which assumes that the ionising particle of the radiations acts directly upon atoms of vital components of the cell or bacteria and no environmental factors can alter or influence the final effect. In view of later researches this theory has had to be greatly modified, and the reader can find a detailed discussion of the shortcomings of the target theory in *Fundamentals of Radiobiology*. Though much more up-to-date information is available in more recently written books, yet the reprinting of Lea's original text will be appreciated by experts engaged in this narrower field because it contains a challenging presentation of certain aspects of radiobiology and many valuable data on the purely physical aspects of radiation. The second edition contains fourteen additional pages, and includes a number of corrections made by Lea himself before his untimely death in 1947.

P. C. KOLLER

Meteor Astronomy

By A. C. B. Lovell (*London, Oxford University Press, 1954, 463 pp., 60s.*)

Since the publication nearly thirty years ago of Olivier's classical treatise, the techniques of visual and photographic observation of meteors have been greatly improved, complete and efficient analyses made of a large mass of data and, finally, the application of the radio-echo technique in this country and in Canada has revolutionised the study of the whole subject.

At this stage, a comprehensive survey is not only desirable but absolutely necessary to a clear understanding of what has already been accomplished and to the appreciation of the problems still to be solved. Prof. Lovell's book is a complete and masterly summary of the subject which is likely to remain the standard work on meteor astronomy for many years to come. Despite the vast amount of information

packed into its pages, the book is eminently readable.

The first three chapters are devoted to a brief description of observational methods, the visual and photographic in the first being followed by two chapters in considerable detail on the history, fundamental features and measurement of radiants and velocities by the radio-echo technique.

The outstanding feature of the progress of meteor astronomy has been the vigorous controversy over the velocity of sporadic meteors, that is to say those meteors which are not part of one of the recognised major showers. Parabolic or hyperbolic? Are we to admit these specks of matter to full membership of the solar system, ranking with planets, planetoids and periodic comets, or are they intruders from outer space? The answer depends upon the exact determination of the geocentric and thence the heliocentric velocity. Prof. Lovell devotes five chapters to this important question. Great prominence is given to the work of Öpik with the Arizona expedition of 1931–33, and rightly, for it was the analysis of this expedition's results that was mainly responsible for the opening shots and subsequent fury of the battle of the velocities. Observational methods (often involving delightful ingenuity), results, analyses, arguments and counter-arguments are given and summarised, the opposition to Öpik being represented by Porter's analysis of the results obtained by the British Astronomical Association team under Prentice and by earlier workers.

The contribution of the photographic technique to the velocity problem provides an interesting chapter, but this branch has entered upon a new epoch with the invention of the optical system known as the Super-Schmidt which is briefly described. This would seem to have revolutionised the photographic method, but results with the new apparatus were not available at the end of 1953.

The final chapter on the sporadic meteor velocities rounds off the subject with a discussion of the radio-echo results obtained independently in Great Britain and Canada. This method uses arrays of Yagi aerials, transmitters radiating 600 pulses per second, each of 10 microseconds' duration. It is more than interesting to compare the results obtained by the visual teams whose principal equipment was and still is a watch, a wand or piece of string and an enviable knowledge of the constellations.

Six chapters follow on the permanent and periodic major showers, including a short but intriguing account of the lost streams of Bielids and Pons-Winnecke meteors, and a longer consideration of the daylight streams—the study of which has become possible by the radio-echo method.

The fundamental equations of motion, the number and mass distribution are given due attention, and the text is completed with a chapter on cosmological relationships, introducing us to a limitless field of speculation. Meteors falling into the sun, time-scales of hundreds of millions of years, "ice" comets, meteors as the debris of comets or comets as the collection of meteor dust—these are a few of the topics discussed here. We leave this last chapter with the feeling that "tho' much is taken, much abides"; problems have been solved and the solutions have provided further problems. Such is the way of science.

It is emphasised that the book does not take account of meteorites or micro-meteorites, very little being known about either; it deals specifically with the astronomy of meteors. We are promised a complementary text of meteor physics at some future date. This will include the general subject of heights which in this volume is introduced only as far as it is concerned with velocity determination. If that second volume proves comparable with the present one, its publication will be greeted with enthusiasm.

W. H. JULIAN

Modern Chemical Discoveries

By Richard Clements (*London, Routledge & Kegan Paul, 1954, 290 pp., 25s.*)

The last edition of Sir William Tilden's *Chemical Discovery* was published seventeen years ago. Instead of bringing up to date that edition because of the great advances in chemistry since that time the author has produced this new book. It is an attempt to introduce all the chemical discoveries of this century up to and including the H-bomb. It deals with nuclear physics, antibiotics, artificial rain, synthetic textiles, anti-malarial drugs, underground gasification of coal and many other advances in the chemical field during the last fifty years. The author is a scientific journalist and he therefore realises the need for clear, lucid explanations and descriptions. In addition, he has produced some really first-rate photographs to illustrate his text.

The first part of the book deals with the atom and there is an excellent account of the history of atomic development in this country and the United States, leading to the atom and hydrogen bombs and the medical and industrial uses of nuclear energy. According to Lord Cherwell nuclear energy may be used in industry to generate electricity by 1960, and the Government has recently announced its plans to carry out such developments. One of the most recent striking uses of atomic power is in the new submarine *Nautilus* which is reported to be able to travel under water at a speed of 20 knots. A few pounds of uranium will give her ample fuel to travel thousands of miles at top speed. This development must be considered as revolutionary as the appearance of the first steamship and points to the future in relation to many forms of transport. There are excellent descriptions of Britain's three new atomic factories in Lancashire, Cheshire and Cumberland and the interrelation of these factories in the vast scheme of utilising nuclear energy. One minor criticism: the chapter on isotopes should perhaps have come earlier in the book, for the sake of clarity to the non-physicist. Nevertheless, this is one of the most explanatory accounts of the whole development of the atom story, and should be invaluable to readers without specialist knowledge.

This book might well have received the title "The Chemical Revolution", for the list of discoveries in recent years seems unlimited. But to understand the science behind these discoveries, it is necessary for the layman to become familiar with chemical terms and processes, and the short chapters on Valency, Catalysts, Colloids and Electrolysis provide the necessary background material.

Part Three deals with developments in inorganic chemistry and the increased knowledge which scientists have gained about the common gases and metals. There is an excellent chapter on the modern methods in use for the refinement of oil and the manufacture of chemicals from petroleum. The chapter on coal-tar is equally interesting, for, as the author says in his opening sentences, "It seems a far cry from the black, sticky, liquid coal-tar to the brilliant dyes for a lady's dress or the little white aspirin tablet. But the black tar is the chemical grandfather of these and many other valuable products which were unknown a few years ago." But again it is the attempt to describe in fairly simple, straightforward language the science behind the discoveries that is the attraction of these chapters. And this is particularly true of the account of the dyestuffs industry; indeed, the story of the discovery of Alcian Blue in 1950 reads like a "thriller". But it must be admitted that the reader without some knowledge of organic chemistry will find himself at a disadvantage.

Drugs and antibiotics receive less space than their importance in the modern world demands. It is a pity that the author had not deemed it necessary to extend these chapters, for his readers are certainly interested in these substances. Penicillin could have provided a chapter in itself.

Personally I was glad to see chapters devoted to hormones and human development, and also plant hormones, which are still in their infancy. The penultimate part of this book describes the advancements which have been made in industrial chemistry—in synthetic rubber, plastics, fertilisers, and the last chapter deals with "The Chemistry of Living Things"—a fascinating study for the scientific observer and one which should stimulate further reading in these subjects. *Modern*

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Chemical Discoveries is a book which should be on the shelf of every student of chemistry. HARRY HOGGAN

Mathematics for the Chemist

By G. J. Kynch (*New York, Academic Press, London, Butterworths Scientific Publications, 1955, 356 pp., 30s.*)

The sub-heading of this book is "Mathematical Analysis for Chemists, Physicists and Chemical Engineers", and the subject matter is based on Prof. Kynch's lectures at the University College of Wales, Aberystwyth. The book is intended to meet the needs of students taking an honours course in chemistry, and also to provide a reference book which gives the mathematical basis for many of the analytical arguments (in the mathematical sense) found in modern physics and physical chemistry.

The author, in his preface, pays tribute to Mellor's book on the same subject which was first published in 1902. The latter set out to teach mathematics to chemists by "leading them up the high hill by gentle slopes". Prof. Kynch has adopted this excellent principle, although the degree of gentleness of the slope will be a matter of some argument. He reminds us quickly of the mathematics which should have been learnt at school, and then carries on to include all the applications of differentiation and integration likely to be required, the properties of and summation of series, complex numbers, differential equations, determinants, vector fields and partial differential equations.

Naturally the treatment of such a wide field cannot be complete, and most people find some section which they would like amplified or extended. For instance, for the Chemical Engineer, the section on Vectors would be made more useful by the inclusion of Gauss's Theorem and its applications. The great value of the present work is that it serves as a bridge between school mathematics and the specialised texts which are apt to defeat the average chemist from the start.

Comparing this book with the earlier work of Mellor, while the latter was written by a chemist for chemists, no one would suspect for a moment that Prof. Kynch is other than a mathematician. He has, however, remembered Michael Faraday's plea to Clerk Maxwell: "When a mathematician engaged in investigating physical actions and results has arrived at his conclusions, may they not be expressed in common language as fully, clearly and definitely as in mathematical formulae?"

Most of his worked examples are phrased in the terms and nomenclature of modern ideas of chemistry, and he does not disdain an occasional application of economic considerations. There are examples to be worked at the end of most chapters, and a useful feature is a list of books which the author has found useful in considering the various sections of the book.

To sum up, this is a book which can be recommended, and at the price it is very good value indeed. E. S. SELLERS

Colorimetric Methods of Analysis

By Foster D. Snell and Cornelia T. Snell (*New York, D. Van Nostrand, London, Macmillan, Vol. 4, 3rd edn. 1954, 676 pp., 93s. 6d.*)

The aim of the authors of this reference work has been to achieve completeness, and, to this end, the third edition has attempted to include, or refer to, all the relevant methods published up to the time of going to press.

This fourth volume contains the second half of the organic and biological material for which room could not be found in Vol. 3. The compounds in each class are briefly introduced and there follows a detailed treatment of the methods applicable to the individual members together with references to the original literature.

The overall result is a highly compressed mass of useful information concerning these methods. D. S. HILL

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FAR AND NEAR

Night Sky in May

The Moon.—Full moon occurs on May 6d 22h 14m U.T., and new moon on May 21d 20h 58m. The following conjunctions with the moon take place:

May

7d 06h	Saturn in conjunction with the moon		Saturn	6° N.
20d 02h	Venus	,,	Venus	6° S.
23d 10h	Mercury	,,	Mercury	2° N.
23d 18h	Mars	,,	Mars	1° N.
25d 17h	Jupiter	,,	Jupiter	3° N.

In addition to these conjunctions with the moon, Jupiter is in conjunction with Pollux on May 6d 18h, Jupiter 6°·3 S.

Mercury sets at 20h 10m, 21h 45m and 21h 30m on May 1, 15 and 31, respectively, and is visible in the western sky. Owing to its increasing N. declination it is better placed for observation in the northern hemisphere than it was in April. *Venus* rises at 3h 50m, 3h 25m and 3h on May 1, 15 and 31 respectively; its stellar magnitude varies between −3·4 and −3·3, and the visible portion of its illuminated disk between 0·837 and 0·904. *Mars* sets at 22h 25m, 22h 15m and 22h on May 1, 15 and 31 respectively, and has an easterly movement from Taurus into Gemini. Towards the end of the month it is close to the stars η and μ Geminorum.

Jupiter, visible until the late night hours, sets at 1h 05m, 0h 20m and 23h 20m on May 1, 15 and 31 respectively. Its eastward movement from south of $\varkappa$ Geminorum into the constellation Cancer is easily observed; its stellar magnitude varies between −1·6 and −1·5 owing to its distance from the earth increasing from 510 to 549 millions of miles during the month. *Saturn* is in opposition on May 9, its times of rising and setting then being approximately those of the setting and rising of the sun. The planet sets in the early morning hours—at 5h 15m, 4h 15m and 3h 10m on May 1, 15 and 31 respectively. It has a slow westward movement towards α Librae and its stellar magnitude varies between 0·3 and 0·4.

The η Aquarid meteors which are active from May 1–6 can be seen in the early morning hours after the moon has set.

Audio: New Landing Aid for Aircraft Carriers

As a further contribution to the safe landing of aircraft on to the flight-deck of aircraft carriers, a new sound device for indicating air-speed has been developed for the Admiralty by the Royal Air Force Institute of Aviation Medicine, and the Ministry of Supply's Royal Aircraft Establishment, both at Farnborough. Known as Audio, it works on the principle of an electric organ and gives its assurance as to correct speed and warning of incorrect speed in the pilot's earphones as a background to the voice reception for which the earphones are primarily intended.

While the sound made by the aircraft was a familiar method for the pilot to assess his speed in the very early days of flying, when some error was acceptable, accurate visual instruments have been used for many years. But the coloured-light system that has been used is not clearly visible in certain conditions and hence it was decided that some other sense should be brought into use.

It so happened that one of the pilots engaged on assessing the new visual aid noticed that, when the colour on his windscreen changed, there was a faint click in the earphones. It was caused electrically. This clue led to the development of Audio.

The apparatus is relatively simple, and is accurate to within a quarter of a knot. It has been tested in a Sea Hawk, and pilots using this system were found to make very few visual references to the conventional air-speed indicator. A Sea Hawk squadron is due to be fitted with Audio in June of this year.

It is expected that Audio will be used in conjunction with the mirror sight and the angled deck, both British conceptions which have decreased Fleet Air Arm accidents.

The leading part in the development of the device, the requirement for which was formulated in Admiralty, was taken by Surgeon Lieutenant-Commander W. H. B. Ellis, A.F.C., M.B., B.S., R.N., a Naval Surgeon who is also a qualified pilot and who is attached to the R.A.F. Institute of Aviation Medicine, and Mr. A. A. Burrows, a scientist at the Institute.

British Patent Fees: First Increase for 35 Years

A patent is a legal right entitling the patentee to restrict the freedom of operation of the general public. Restraint of freedom is generally regarded with disfavour, and for that reason the grant of patents and administration of patent law are subject to strict regulations which call for considerable administrative activity by a large staff of examiners and clerical officers at the Patent Office. In order to meet the expenses of such an organisation fees are charged to applicants for patents, and to patentees, in respect of their applications, and the grant of patents thereon. In a few countries, notably the U.S.A., a patent when granted remains in force for its full term without any further demand for payment, but in most countries, including the United Kingdom, yearly renewal fees must be paid in advance if the patentee desires to retain his rights. Other fees are also called for in respect of various ancillary services provided by the Patent Office in connexion with patent applications and patents.

In this country, with a very few exceptions, the fees payable to the Patent Office for its different services have remained unchanged for at least thirty-five years, but some important increases are now introduced by the Patents (Amendments) Rules, 1955, which came into force on February 1, 1955.

The most important increases from the point of view of an applicant or patentee are in respect of the sealing fee (payable after an application has been accepted in order to secure grant of a patent thereon), and the annual renewal fees. The sealing fee, heretofore £1, is now to be £3, and the annual renewal fees (heretofore £5 in respect of the fifth year of life of the patent, £6 in respect of the sixth year, £7 in respect of the seventh year, and so on, up to £16 in respect of the sixteenth, which is normally the last year during which the patent could be kept in force) now increase more steeply. The new fees, payable before expiry of the preceding year of the life of the patent, are as follows: in respect of the fifth year, £5; in respect of the seventh, and sixteenth years the fees are £8 and £20 respectively.

The Patents (Amendments) Rules, 1955, setting out in full all the increased fees are published by H.M. Stationery Office at 1*s.* 9*d.*

Presumably these comparatively small increases will have little or no effect upon applications for, and maintenance of, patents covering valuable inventions, but it is possible that fewer applications will be lodged, or patents kept in force, in respect of inventions of little technical merit or commercial value. To that extent the field might become somewhat freer for development of really meritorious inventions, although on the other side of the picture the small free-lance inventor, with limited finance available, may feel that he is being unduly penalised. To what extent that is morally justifiable is a point upon which opinions will no doubt differ.

A Substitute for Lime Sulphur

American trials of a new fungicide known as S.R.406 suggested that it might prove an excellent substitute for lime sulphur, particularly on "sulphur-shy" varieties of apple. This fungicide is now available in Britain under the name of Captan, and trials made by Plant Protection at Fernhurst show that it controls apple scab at least as well and usually better than sulphur sprays. It seems, however, to have little, if any, effect on apple mildew.

University Courses in Nuclear Engineering and Radio-isotopes

The first full-time course in nuclear engineering at Manchester University was completed in March. This course, lasting six weeks, was designed to give an introduction, suitable in the main for engineering graduates, to the new techniques involved in the design and manufacture of atomic reactors for the commercial production of electricity. Six of the twenty-five students attending the course came from the Industrial Atomic Energy Group—an organisation set up last year jointly by the Associated Electrical Industries Ltd., and the John Thompson firm of Wolverhampton—which has premises in Manchester and is concerned with developing designs for power reactors more advanced than the one now being built at Calder Hall in Cumberland.

Birmingham University is in October to start advanced courses in radioactivity and radiochemistry to give specialised training to those intending to use radio-isotopes in industry or medicine.

New Fellows of the Royal Society

The following scientists have been elected Fellows of the Royal Society:

PROF. DAVID ROBERT BATES, Professor of Applied Mathematics, the Queen's University, Belfast. Distinguished for his contributions to theoretical atomic physics and its application to the interpretation of phenomena in the earth's atmosphere.

DR. EDRED JOHN HENRY CORNER, Lecturer in Botany, Cambridge University. Distinguished for his researches on fungi and on tropical floras.

PROF. ALAN HOWARD COTTRELL, Professor of Physical Metallurgy, Birmingham University. Distinguished for his researches into the mechanical properties of metals.

PROF. SAMUEL DEVONS, Professor of Physics, Imperial College of Science and Technology, London. Distinguished for his researches in nuclear physics, including the investigation of short-lived states of nuclei.

PROF. ALLAN WATT DOWNIE, Professor of Bacteriology, Liverpool University. Distinguished for his contributions to bacteriology and virology.

PROF. KINGSLEY CHARLES DUNHAM, Professor of Geology, Durham University. Distinguished for his petrological researches, his work on the genesis of ore deposits, and on the stratigraphy of the north of England.

DR. DAVID JOHN FINNEY, Reader in Statistics at Aberdeen University and Director of the Agricultural Research Council's Unit of Statistics. Distinguished for his work in the development and application of statistics to biological problems, especially in the field of bioassay.

DR. ALEXANDER FLECK, Chairman, I.C.I. Ltd. Distinguished for his contributions to chemical technology and his pioneering work on the radioactive elements.

PROF. KENNETH JAMES FRANKLIN, Professor of Physiology, St. Bartholomew's Hospital Medical College, London. Distinguished for the application of x-ray cinematography to physiological problems, for work on veins and vascular reflexes, and the history of physiology.

PROF. WILLIAM REDE HAWTHORNE, Professor of Thermodynamics, Cambridge University. Distinguished for his researches in the combination of thermodynamics and hydrodynamics on which the design of high-speed heat engines is based.

PROF. DONALD HOLROYDE HEY, Daniell Professor of Chemistry, King's College, London. Distinguished for his original contributions to the study of free radicals of short life as intermediates in chemical reactions, and to synthetic organic chemistry.

SIR HAROLD PERCIVAL HIMSWORTH, Secretary of the Medical Research Council, London. Distinguished for his contributions to clinical investigation, and especially for researches into the aetiology of diabetes mellitus and liver necrosis.

DR. ANDREW FIELDING HUXLEY, Assistant Director of Research in Physiology, Cambridge University. Distinguished for fundamental discoveries concerning the conduction of impulses in nerves, and for developing new methods for the study of nerves and muscles.

PROF. REGINALD WILLIAM JAMES, Professor of Physics, Cape Town University, S. Africa. Distinguished for investigations of the structure of matter through the use of x-rays, and particularly for his studies of thermal motions of atoms in crystals.

DR. DAN LEWIS, Head of Genetics Department, John Innes Horticultural Institution, Bayfordbury, Hertfordshire. Distinguished for his researches on the genetics and physiology of pollination.

DR. JOHN WILFRID LINNETT, Lecturer and Demonstrator in Chemistry, Oxford University. Distinguished for his work on molecular structure and on the physical chemistry of combustion and flame propagation.

PROF. ALFRED CHARLES BERNARD LOVELL, Professor of Radio Astronomy, Manchester University. Distinguished for his contributions to radio astronomy, and in particular for his work on the detection and investigation of meteors by radio methods.

PROF. OTTO EGON LOWENSTEIN, Mason Professor of Zoology and Comparative Physiology, Birmingham University. Distinguished for his work on the comparative physiology of the vertebrate labyrinth.

DR. RAYMOND ARTHUR LYTTLETON, Lecturer in Mathematics, Cambridge University. Distinguished for his original contributions to theoretical astronomy and astrophysics and for his mathematical researches on rotating liquid masses.

DR. ALEXANDER GEORGE OGSTON, Lecturer in Biochemistry, Oxford University. Distinguished for the application of physicochemical principles and methods to biological problems.

DR. GUIDO PONTECORVO, Reader in Genetics, Glasgow University. Distinguished for his contributions to genetics, especially by his studies of gene action, gene organisation, and systems of variation in fungi.

DR. JAMES ARTHUR RAMSAY, Lecturer in Zoology, Cambridge University. Distinguished for his analysis of factors controlling the water balance in animals and for the elegance of the micromethods he has devised.

DR. FREDERICK CLIFFORD TOMPKINS, Reader in Physical Chemistry, Imperial College of Science and Technology, London. Distinguished for his experimental and theoretical contributions to the study of physical and chemical adsorption, and the thermal decomposition of ionic solids.

PROF. ARTHUR GEOFFREY WALKER, Professor of Pure Mathematics, Liverpool University. Distinguished for his work on foundations of relativity theory, and for important contributions to differential geometry, including theory of harmonic spaces and the theory of fibre bundles.

PROF. GEORGE PHILIP WELLS, Professor of Zoology, University College, London. Distinguished for his studies relating structure and function to mode of life of invertebrate animals particularly of polychaetes.

Annual Report of DSIR

The latest annual report of the Department of Scientific and Industrial Research (Cmd. 9386, H.M. Stationery Office, 9*s*.) is a 326-page document with an adequate subject index. Of major interest are the DSIR Advisory Council's recommendations for using the increased resources being made available to the department in the period 1954–9. The principal provisions of the "Five Year Plan" are for an increase of staff over five years of 1000 (bringing the total in 1959 to about 5100); for an increase of about £900,000 (or about 20%) in the annual net Vote of the Department over that period of about £6 million.

The estimated expenditure for 1954–5 is just under £6,300,000. The figure for the increase in staff in the same year is about 200. The Advisory Council recommended that rather more than two-thirds of the total should be distributed among five research laboratories most urgently in need and dealing respectively with Mechanical Engineering Research, Fuel Research, Road Research, Water Pollution and Hydraulics Research Station.

The DSIR looks after the details of British collaboration in the affairs of the European Organisation for Nuclear

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NEW FELLOWS OF THE ROYAL SOCIETY

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PROF. S. DEVONS

PROF. A. W. DOWNIE

PROF. K. C. DUNHAM

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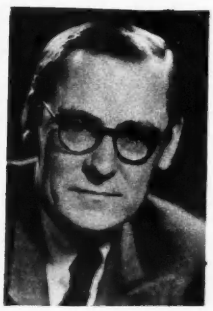

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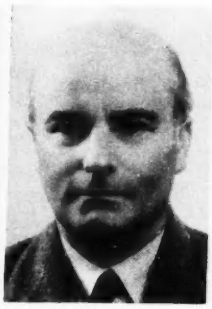

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SIR HAROLD HIMSWORTH

PROF. R. W. JAMES

DR. D. LEWIS

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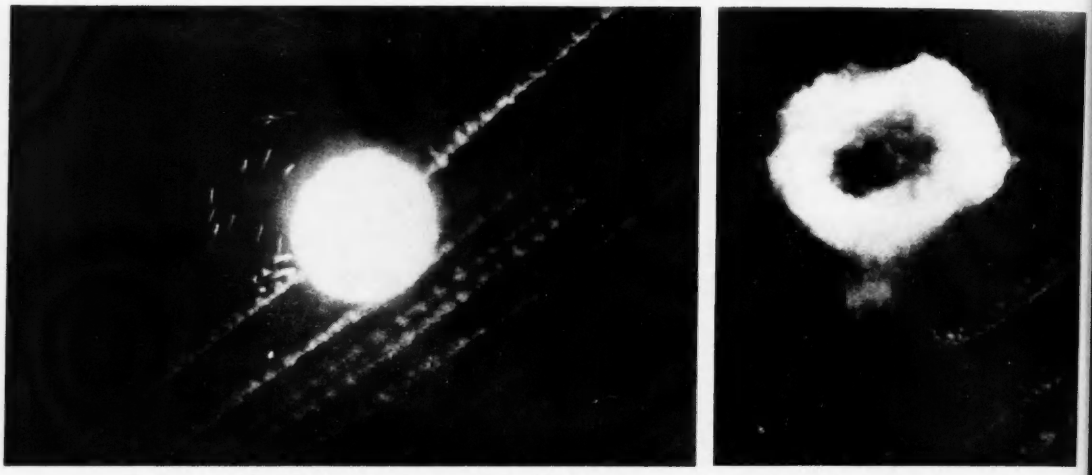
DR. G. PONTECORVO

PROF. A. G. WALKER



A nuclear explosion six miles above the earth. In April in the course of the latest series of nuclear weapon tests held in the Nevada desert the U.S. Atomic Energy Commission burst one bomb high in the air: the purpose of this particular test was to measure the effectiveness of an aerial nuclear weapon designed to destroy an entire force of enemy planes without injuring troops on the ground. This atomic device was dropped from a B-36. The streaks in the photographs are smoke trails laid by other planes so that the spread of the blast could be followed. The lefthand photograph shows the original fireball of the exploding bomb, and the other shows the ring-shaped cloud. Sir William Penney of Britain's Atomic Energy Authority witnessed this test.

Research, whose laboratory near Geneva is now under construction. The department's secretary, Sir Ben Lockspeiser, is president of the organisation, to which Britain's estimated contribution for 1954–5 is about £360,000.

The report records progress made in all the various DSIR laboratories, and also in the different Research Associations which the department supports financially. A rich variety of research and development items are mentioned. One finds, for example, that the Electrical Research Association's work on the double-purpose heat pump (to provide hot water and cool the larder at the same time) has reached the commercial stage and will be tested on a housing estate. ASLIB is one organisation that receives a DSIR grant, and the report states that it has published the first issue of an annual *Index to Theses Accepted for Higher Degree in the Universities of Great Britain and Ireland.*

Radio Industry Council's Premiums for Technical Authors

This year the Radio Industry Council has awarded six premiums of 25 guineas under the scheme started in 1952 to encourage the writing of articles on radio and electronics. The following is the list of prizewinners: Dr. J. M. M. Pinkerton, E. J. Kaye, E. H. Lenaerts, G. R. Gibbs, H. S. Jewitt, J. F. Field, D. H. Towns, W. R. Cass, R. M. Hadfield and A. E. Maine.

A Safe Chlorate Weedkiller

The first chlorate weedkiller which carries no fire risk has been put on the market by Borax Consolidated (Borax House, Carlisle Place, London, S.W.1). This mixture of chlorate and borate is made by a process covered by a British patent (No. 701,057). Known as Polybor Chlorate, this product can be used around outdoor structures and buildings of all kinds, on paths, timberyards, parking-areas and railbeds. The absence of fire risk allows its use around petroleum refineries, in oil storage areas and chemical plants.

Exhibitions

Latest developments in scientific and electrical instruments, industrial meters, etc., will be shown at the third British Instrument Industries' Exhibition, to be held at Earl's Court, London, from June 28 to July. 9. The exhibition is organised by F. W. Bridges and Sons Ltd., and its sponsors include the Scientific Instrument Manufacturers' Association.

The annual exhibition organised by the Northern Division of the Institution of Electronics will be held at the Manchester College of Technology, during the period July 14–20, 1955. The hon. exhibition organising secretary is Mr. W. Birtwistle, 78 Shaw Road, Rochdale, Lancs.

Titanium at the B.I.F.

Of particular interest on I.C.I. Metal Division's stand at the Castle Bromwich section of the B.I.F. will be the display of wrought titanium products, with emphasis on application in the aircraft industry. I.C.I.'s new plant in the north of England for the manufacture of 1500 tons of raw titanium a year is due to come into full operation by early autumn.

A New Nature Reserve

The Nature Conservancy has declared one new nature reserve in England, and are adding a further area to the existing reserve, at Scolt Head, Norfolk. The new reserve is the Axmouth-Lyme Regis Undercliffs Nature Reserve between Seaton and Lyme Regis, Devon. It stretches along 5¼ miles of coast and covers 708 acres, is primarily of geological interest and is the most important landslip area on the British coast. Permits are available for research purposes from: The Regional Officer for the South-West, The Nature Conservancy, Furzebrook Research Station, Wareham, Dorset.

A Scientific Society Meets at Harwell

The opening of a large lecture theatre outside the security fence at the Atomic Energy Research Establishment made it possible for Harwell to invite the Physical Society to hold a meeting there on March 31 and April 1. The subject under discussion was Nuclear Energy Levels and Neutron Physics. The conference ended with a visit to the Harwell laboratories on the morning of Saturday, April 2.

Cambridge Ph.D. Theses

Cambridge University has published a 272-page book containing Abstracts of Dissertations approved for the Ph.D., M.Sc. and M.Litt. Degrees during the year 1952–3. The full theses can be consulted in the University Library.

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